ENTAL IMPACT STATEMENT ON

OIL AND GAS DRILLING & PRODUCTION IN MONTANA

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

TECHNICAL APPENDIX 1

SEISMIC AND OTHER GEOPHYSICAL EXPLORATION METHODS

Once a lease is obtained, the decision to locate a well in a particular place is usually based upon a geologic interpretation of the subsurface rocks, including structural and stratigraphic configurations. Other factors affecting the drilling location are physical limitations due to surface features and legal requirements such as well spacing, subdivision line setbacks, and topographic tolerance requirements set by the Board.

Geologic interpretation of subsurface rocks is made by scientists who use information from both surface and subsurface sources. Surface data are obtained by actual field work and from aerial photographs. The two principal sources of subsurface information are existing well data and geophysical mapping. These interpretations are intended to reveal possible deposits of hydrocarbons.

Three key conditions must simultaneously exist to accommodate commercial quantities of oil and gas. First, there must be a shale-like rock with a high percentage of organic material capable of generating oil or gas when subjected to the right combination of heat and pressure at depth in the earth. Second, there must be a reservoir rock such as a porous sandstone, limestone or dolomite that the hydrocarbons can flow into and collect in large volumes. Lastly, there must be a trapping mechanism such as a dome, a fault, or a barrier of nonporous rock to keep the hydrocarbons from leaking out and escaping to the atmosphere.

Exploration geologists must use a combination of tools and methods to provide as many pieces of the hidden puzzle as possible, since no single tool or combination of tools yet invented can actually detect oil or gas without drilling.

There are two common ways of determining where seismic crews should conduct their mapping. First, where a company or group of companies controls leasehold interests in a prospective area, their geologists will determine where seismic testing should be performed to test and refine their theoretical model of subsurface structures. Siesmic lines often cover subsurface targets several miles in areal extent.

In other cases, seismic test sites are selected by a company that does not own any oil leases, but which is attempting to generate and sell subsurface information. They also use a scientific approach in selecting regions for "speculative" seismic shooting in hopes that they can sell the data. Seismic companies seek the same type of data as an oil company, but seismic company data cover much larger areas. Common "spec data" may include hundreds of linear miles of seismic testing covering entire national forests or counties. Expensive shooting in rugged terrain can cost upwards of $20,000 per mile and spec shoots may require a number of pre-paid purchase agreements to finance a risky program such as in the Montana Overthrust.

Seismic data collection is highly visible because it uses high explosives or heavy vibrating trucks. An array of detectors called geophones is laid out

in a specific pattern and connected to a central gathering and recording unit. The blast or vibrating trucks generate "S" and "P" seismic waves that the subsurface rock formations reflect and refract back to the geophones. A computer system converts the raw data into two- and three-dimensional images of the subsurface formations, including different density variations in rocks or stratigraphic traps and structural traps.

The three most widely used seismic test methods in Montana are the shot hole, Vibroseis, and the Poulter (air blast). Each has its own applications and impacts on the surface of the land. The shot-hole seismic method places explosive charges on bedrock at the bottom of drill holes so that maximum energy can be transmitted into solid rock. It is used where valley fill or some other unconsolidated material covering the bedrock interferes with the quality of the signal. This method requires drilling holes 6 inches in diameter and 100 to 200 feet deep at intervals of 200 to 400 feet over several miles. The holes are charged with explosives and filled back in before detonation. The majority of shot holes do not blow out, and nothing louder than a subdued "thump" can be heard when standing next to the hole. Blowouts occasionally occur and must be filled back in to prevent permanent cratering. Reclamation crews clean up around the holes by picking up litter and smoothing out drill cuttings so that vegetation can grow back. This method has potential for mixing of surface water with potable groundwater through the shot holes. Proper plugging with bentonite clay solves this concern in most cases. Current rules on plugging by the Board of Oil and Gas are intended to prevent these problems. Other problems can result if careless operators use heavy vehicles in soft soils and cause ruts, or if explosives are detonated in holes that have not been refilled.

Vibroseis is a patented method using a series of vibrating trucks to generate seismic waves. Signals generated by these trucks are detected and recorded as with the shot-hole method. This method is used where the signal can be adequately transmitted through the ground from the surface and where large trucks can easily drive. Vibroseis often is done on local and county roads and has much less impact than drill holes. Soil compaction and the effects of clearing vegetation in long straight lines to allow passage of vibrator trucks are the main impacts of this method.

The Poulter or Air Blast method uses explosives hung on sticks several feet above the ground. The shock wave enters the ground from the air but most of the energy is lost upward creating a loud noise. This method is used where surface access is difficult such as in heavy mountainous terrain. Such an operation usually depends on helicopters for transportation and requires only foot traffic on the surface. Impacts of this method include fire danger, disruption of wildlife, and human annoyance. Crews used in this method tend to be large, usually two 25-man groups hopscotching to set up explosives, lay out and collect geophones, and clean up after shooting.

Many other geophysical and geochemical methods are used to detect subsurface structure and hydrocarbons, but most require only a single aircraft or all-terrain vehicle and are much less noticeable. Briefly, these are: (1) gravity surveys that can detect changes in rock density; (2) magnetic surveys to detect the disturbance in the earth's magnetic field due to metal-rich rocks; (3) resistance- and induced-polarization surveys to detect change in the earth's reaction to man-made electrical current; (4) telluric surveys to

measure variations in the flow of natural electrical current in the earth's crust; (5) hydrocarbon sniffing to detect low level seeps; (6) vegetation surveys to map hydrocarbon seeps; (7) aerial and satellite photography to plot large structural trends and vegetational changes; and (8) other scientifically sound but less notable methods. Well witching and other mysterious methods of an unexplainable or metaphysical nature have been tested but no record of consistent reproducible success has ever been attributed to these.

Geophysical testing performed down the borehole can include most of the above tests, plus others such as native gamma radiation, neutron density, and dip surveys to detect deviations from vertical. These tests are called electrical "logging" of the well and are performed by a specialty company that lowers test tools down the open borehole on a wire line and then retrieves them, recording measurements along the way out. Stratigraphic correlations from well to well help determine the shape and size of hydrocarbon reservoirs. Since oil is normally found in porous rock and not in underground lakes or pools, some of the tools record rock density and porosity. More specific tests tell geologists whether the reservoir will produce commercial quantities of hydrocarbons. If the logs and tests are not encouraging, most wells are declared to be "dry holes" and are plugged while the drilling rig is still in place. If the logs show good results, the well may be drilled deeper or casing be inserted to "complete" the well at its existing depth.

NOTES FROM INTERVIEWS WITH BOARD INSPECTORS

Drilling Site and Access Road Construction

Access road location and construction methods are agreed upon between the oil company and the landowner without Board involvement. Existing roads and tracks are used to the greatest extent feasible and are generally only upgraded to the minimum quality necessary to get the required equipment into the drilling site, or in some cases to accommodate a landowner's request for an upgraded road. Where new access is required, the company will generally do the minimum amount and quality of construction feasible. No blading will normally be done where the terrain and the nature of the drilling equipment make it possible for the operator to drive over open country to the drill site. Companies also will seek exceptions to the Board's well spacing rules in order to avoid rough terrain and road construction.

Topsoil is virtually always stockpiled when present. This is not a Board requirement but does constitute standard industry practice.

Water for the drilling operation is typically obtained from the nearest stock pond, reservoir or spring, usually as part of the negotiations with the landowner for the overall drilling operation. Normally the presence of water wells in the vicinity of a drilling site is not considered a problem. The Board's rules require that surface casing must be set below the depth of all potable fresh water that is reasonably accessible for agricultural and domestic use. Also, the rules require that only freshwater-based drilling fluid may be used when drilling through freshwater aquifers anywhere in the state. If the landowner has any special concerns about water wells, these would be part of the pre-drilling negotiations and agreements between the company and the landowner. One of the Board's inspectors noted that the

inspectors do not have data showing the locations of these wells and such data are not submitted with drilling applications.

Reserve Pit Construction

Reserve pits vary in size among the oil and gas producing regions in Montana, ranging from approximately 30 ft x 150 ft x (depth) in the Williston Basin to 75 ft x 100 ft x 8 ft in central and southern Montana. In northern Montana, reserve pits are typically 12 ft x 40 ft x 6 ft for a double rig and 40 ft x 70 ft x 8 ft for a triple rig. The size of the pit is dictated primarily by the depth of the target strata and the amount of drilling mud and cuttings that must be accommodated. The location of the reserve pit is dictated by the location of the drilling rig. Oil company representatives normally discuss the reserve pit location with the landowner but not with the Board before site construction begins.

Virtually all reserve pits in the Williston Basin are lined with 12-14 mill reinforced polyethelene or other plastic liners due to the prevalence of gravel and other permeable soils and the saltwater-based muds used for drilling in the Williston Basin. According to the Board's staff, the liner requirement is indicated by a special stamp on the drilling permit. Installation of the liners is already standard industry practice in the area. In some cases the operator purchases produced water (current costs are about $2/barrel) for use in mixing the drilling mud. If the drilling fluid is obtained by adding salt to freshwater, the typical rate 125 pounds of salt per barrel of water. There is both an economic incentive and an environmental rationale for ensuring that these fluids are contained. The fluids in the reserve pit at a saltwater drilling operation are usually kept to no more than 1-2 ft deep.

The pit liners used in the Williston are generally 125 ft x 250 ft. Several companies specialized in liner installation during the boom of the late 1970s and early 1980s. At present most people who provide site construction and dirt-working services in the Williston Basin have experience with installing the liners. Standard practice is to trench around the sides of the excavated pit and bury the corners of the liner. The installers must be careful to avoid stretching the liner and to leave sufficient slack in the bottom to avoid perforating it on rocks. Also, the liner should not be installed very far in advance of drilling or there can be problems with it billowing up in the wind and tearing.

Pit liners are also common in areas along the Overthrust where the surface is primarily composed of glacial till, tailing material, and other porous material. In most other portions of the northern and Overthrust regions and in the central and southern producing basins, reserve pits are virtually never lined. This is because the drilling operations in these areas use fresh water. Diesel or oil-based drilling muds may be used in special situations, but these are relatively rare and care is taken to avoid loss of these expensive fluids.

If the dikes or sides of a reserve pit were to show seepage or if the level of fluid in the pit were to begin dropping, "gel" or drilling mud composed primarily of bentonite and freshwater chemicals added to control the loss of water would be added to seal the bottom and sides. Also, the

drilling muds tend to act as a sealer and thereby to prevent fluids from filtering downward. In most situations, a significant volume of fluid would have to escape before a leak would be detected unless it were on the side of a berm or dike.

Reserve pits are commonly fenced if there is livestock in the vicinity, but this is not a formal requirement.

The Board's inspectors have seldom found it necessary to condemn a reserve pit. Occasionally, on a site-specific basis, the inspector may require the operator to install a dike or improve the existing dike around a pit. If a leak is discovered (for example in a berm or dike), the inspector informs the responsible party that repairs are needed. If the repairs are not made, the inspector's next step would be to send a letter documenting the problem and the necessary corrective action. If the operator still failed to comply, the inspector could recommend to the Board that the pit be condemned. When the reserve pit contains primarily fresh water and bentonite, a leak is not considered a major problem.

Reserve Pit Reclamation

Reserve pit reclamation methods also vary among the oil and gas producing regions, with certain methods being unique to the Williston Basin. In most areas of the state, except for the central and south-central regions, the "top water" or fluids remaining ater completion of drilling on the surface of the pit are suctioned up and taken to disposal wells. In cases were drilling results in a dry hole, the fluids may be pumped back down the hole as part of the plugging operation. In some cases, particularly where there are no disposal wells nearby or where the landowner is not immediately concerned about resuming use of the surface, such as on margilal rangeland, the pit may be left to dry out for three or four months. If oil residue remains after the top water is taken off or evaporated, this will be skimmed or vacuumed up. The volume would typically be less than one barrel.

At this point, the pit is filled in. Dirt is usually mounded on top to allow for settling. Occasionally a landowner will request that the pit muds be taken out and used to help plug or reinforce a water reservoir or dike. Also, landowners have occasionally requested that the reserve pit muds be spread on their fields. However, the muds are typically left in the pit.

In the Williston Basin, the most common method of pit reclamation is to break or tear the liner after the top water has been hauled away, dig trenches to drain any remaining muds, and then backfill the pit. The layer of mud in the bottom of the pit is typically about 2 feet thick. About 2 feet or so of soil is added initially, and the pit may be left to settle for up to a year before a final "top dressing" of soil is added to completely fill it. The trenching method is favored because the salt-based mud and fluids take longer to dry out than freshwater muds and the pits in the Williston area also tend to be somewhat larger than in other parts of the state, requiring a longer period of time for fluids to evaporate. Experience has shown that if the liner is not breached, any residual fluids will initially be trapped and then as the mud slowly dries out it will shrink and leave hollow spaces under the surface of the filled-in pit. This creates a hazard for vehicles or farm machinery that may be driven over the site. Also, the pit may remain unstable

and soggy in the subsurface for an indefinite period if trenching is not done.

The pit muds tend to seal the bottom of a reclaimed pit in much the same way that they seal the sides of the wellbore. Since the pit is 8-10 feet deep, the mud is buried below the root zone of crops. The Board's inspectors feel that if rain or irrigation water percolates down to the buried mud and drainage trenches, it will run over or around the mud. Potential groundwater contamination is not considered very likely nor is any contamination that might occur considered a major problem because of the relatively small amount of mud present. Also, at least one inspector noted that he advises companies to use only EPA-approved substances as mud additives and that in his experience this constitutes standard industry practice anyway. Trenching also is considered an improvement over past pit reclamation practices dating back to the 1950s when the pits would be either left open for as long as several years or up to 3-4 feet of mud might be left in the bottom. Rain water would percolate down to this layer and be trapped and salt crystals would develop. This created special problems on croplands because wheat would not survive beyond six or seven weeks on these older pit sites.

The main exception to the trenching method of lined pit reclamation is along the Cedar Creek Anticline where the pit liners are most commonly folded in and buried with the contents intact. This practice requires a special technique and is labor intensive. Because the Cedar Creek area is pasture land rather than cropland and because the soils tend to be drier and primarily consist of heavy clays, the muds do not tend to remain soggy or create the other problems experienced further north when trenching is not done. Also, there are numerous pipelines throughout the Cedar Creek area and trenching could interfere with these lines.

Special techniques can stabilize the pit muds and minimize the potential for water leaching down beneath the site if this is deemed necessary, as might be the case at a site closely underlain by a shallow freshwater aquifer. One such method uses centrifugal force to spin as much fluid as possible out of the mud and then gypsum is added to absorb any remaining moisture and further stabilize the pit contents. However, this procedure is expensive and is rarely done.

Site Abandonment and Reclamation (Dry Holes)

A Board rule requires that the surface of a drilling site must be restored to its previous grade and productive capability and that measures must be taken as necessary to prevent adverse hydrological effects from the plugged hole. There are no written guidelines for judging the success of site reclamation efforts. All of the inspectors noted that most aspects of site reclamation are agreed to by the landowner and the oil company prior to site abandonment. Also, the inspectors check with the landowner before specifying any particular reclamation measures. The Board's inspectors have no involvement in road reclamation or in decisions about whether the access road will be left unreclaimed.

Often (up to 50 percent of the time in some areas), the landowner performs the reclamation measures, which normally is the most effective

approach since it is not uncommon for reseeding to occur two or three times before it is successful.

Most sites are ripped to a depth of 2 to 3 feet to eliminate soil compaction problems. On cropland, a springtooth typically would be used after the ripping to prepare the surface for reseeding. On rangeland that is not bladed or otherwise disturbed except for vehicles driving over it, the land is left to reclaim itself. One problem that ripping can cause is mixing the topsoil with the subsoil and thereby reducing soil fertility.

The choice of reseeding mixtures is usually decided between the oil company and the landowner or by the contractor who is responsible for reclamation. If an inspector is asked for information abour seed mixtures, he may check with the Soil Conservation Service or refer to the list of species the federal land management agencies require to be used on similar federal lands in the area. Reseeding may be done in either the spring or fall, depending on when moisture conditions are most favorable. The seed may or may not be drilled into the soil, depending on site conditions. Mulching and addition of fertilizer are not common practices.

Normally the inspector will wait between three months and one year before first visiting a reclaimed site. For cropland, this period is most commonly three to six months. The inspector usually photographs the site during the first inspection. If the results are not acceptable, the inspector will talk with the landowner to determine his expectations for the site and either wait another growing season before checking the site again or call the contractor to come back and reseed. In many cases, particularly in pasture land and during periods of drought, it is not uncommon for reclamation to take two growing seasons.

Some sites are very difficult to return to original condition. Among these are Colorado shales, badlands, and areas of the Missouri Breaks where high concentrations of dissolved minerals tend to shed moisture. One inspector said he has encountered situations where the landowner was willing to accept that a site had been successfully reclaimed when the inspector would not have approved it. In those cases, the inspector asked the landowner to sign a release form in order to avoid future problems with either the same owner or new owners if the reclamation was later considered a failure.

The inspector's decision on whether to release a company's bond for a particular site is primarily based on whether the revegetated area looks similar to or better than the surrounding area. This is usually a more straightforward determination on cropland than on range or pasture land because the landowner will typically be farming the cropland as soon as it is feasible to do so. The inspector also will check to ensure that there are no large holes or low areas and that the site is reasonably contoured to resemble its former shape or to blend with the surrounding terrain.

One inspector noted that it is usually not a major problem to get a company to come back and reseed a site even in cases where the bond has already been released. Also, if he sees that revegetation is failing, for example where livestock have trampled it, the inspector carries a bag of seed along on field trips, and he will reseed an area himself if the problem does not appear to be major.

Production Sites and Reclamation

Final reclamation and abandonment of production wells and fields is more complicated because all of the facilities must be removed. In cases where the surface has absorbed oil and other hydrocarbons over years of production, this material would typically be buried and new topsoil brought in. The Board's inspectors are not involved in decisions concerning the placement of production facilities such as tank batteries and heater treaters. The operation and maintenance of production facilities is solely the responsibility of the oil or gas company, unless a routine inspection turns up an obvious problem such as inadequate height, or capacity of dikes around tanks, or a leak in a dike. Batteries are typically constructed a minimum of 150 feet from the wellhead, and the dike system surrounding the batteries is supposed to be 1.5 times the capacity of the batteries or tanks.

Portions of producing sites are typically reclaimed when the well is completed. For example, the reserve pit and solid waste disposal pits are filled and reseeded. When production is about to commence, the access road to a site is typically improved or upgraded to the degree necessary to accommodate the vehicles needed to reach the site on a regular basis.

Produced Water Disposal

Most of the produced water in the Williston Basin is taken to underground disposal wells which are relatively numerous in the area. This water is typically stored in tanks at the well site where it was produced and then transported in trucks or a pipeline to a disposal well. Earthern evaporation pits are uncommon in the Williston Basin.

Earthen pits are quite common in the Cedar Creek Anticline where the surface soils are primarily heavy clays impermeable to water. These pits typically hold three or four days volume of produced water. Produced water pits are generally uncommon in central and south-central Montana, primarily because there are so many secondary recovery operations which provide a ready disposal source for the water. Produced water in those areas is generally of a quality that can be used for livestock.

Surface pits for storage of produced water are very common in northern Montana due to the large volumes of water produced in the older fields and the few disposal wells in this region. Secondary recovery operations using waterflood are numerous in northern Montana, but the operators are reluctant to take produced water with high sodium chloride (salt) content because bacteria will readily grow in it.

Most northern-producing fields have emergency surface pits near the heater treaters. These pits are not lined, but fluids placed in these pits usually are removed within a day.

There is no formal definition or standard for "salt or brackish water" as this term is used in the Board's rules concerning waters that must be properly impounded. However, some of the Board's inspectors consider brackish water to mean water containing 10,000 parts per million or more of total dissolved solids. In practice, the meaning of the term "brackish" is relative

because of the wide range of natural water quality throughout the state as compared to the quality of produced water. For example, in portions of the northern region, the water produced with oil and gas is as good as or better than the water residents are using for domestic purposes or to water their livestock. Also, as discussed further in the section on Water Quality, there are two known active permits--Berenezy Corp and Silver Fox--where produced water is discharged to the surface. In some cases, particularly during a drought, landowners may request that produced water pits be left open for their stock to use even if the TDS content is in excess of what would normally be acceptable.

Weed Management

Weed problems are generally not created or worsened in any major way by oil and gas drilling and development. Complaints from landowners about weed infestations caused by oil and gas activity are few to nonexistent. None of the Board's inspectors felt that seed transport by oilfield vehicles increases weed problems. Landowners have occasionally complained that stockpiled topsoil, especially off the drilling site, has caused more weeds to grow. Also, weeds are not a major problem in croplands because cultivation tends to eliminate them. Companies normally spray weeds around production facilities, although this has been noticeably less prevalent during the recent economic downturn in the industry. Weed control issues, if any, typically are worked out between the company and landowners without Board involvement. The inspectors are not in contact with county weed control personnel nor are these persons normally involved in any way with oil and gas operations.

Spills

Although the Board has authority to require clean up of hydrocarbon spills, there are no written guidelines or procedures concerning the sequence of actions necessary to respond to spills. The inspectors feel that the industry takes spills seriously and normally will clean them up immediately. If an accident occurs in a drainage or near a live stream, the Water Quality Bureau should be informed. In some cases, the Water Quality Bureau has been informed of spills that were not known to the Board until several days later.

In cases where a major spill makes it impossible to grow a crop or reclaim a site, the inspector would recommend that the company's bond not be released. Oil spillage areas normally can be revegetated with native plants over a period of time. The most serious short-term problems occur when there is a spill in a drainage or in an area underlain by porous soils.

DISTRICT: WESTERN MONTANA (OVERTHRUST AND DISTURBED BELT)

MAXIMUM COMMON WELL DEPTH: Average depth 12,000 ft with a high variance in individual locations ranging from 6,000 to 18,000 ft. Seeking all formations Tertiary through PreCambrian.

PRODUCTS:
1) oil with associated gas
2) gas with condensate
3) carbon dioxide

DRILLING:

1. Rig Size/Type: Triple derrick, jack-knife type
   Diesel or diesel-electric
   Weight: rig about 2,000,000 lbs
   Height: 160 ft (assumes 20 ft substructure)
   Engine: 1500-2000 horsepower from 3 engines
   Requires: 40-50 one-way semi-truck loads to move rig to site at 45,000 lbs per loads
   Derrick capacity - 1 million lbs

2. Crew Size:
   1) Rig Crew: 4-5 persons on rig per 3 shifts, 8 hours each shift. Workers include: driller, derrick man, motorman, chain hand, and sample catcher.
   2) Support Crew: 4-5 persons on rig per shift, 2 shifts 1 week on, 1 week off except mud loggers who are 12 hours on, 12 hours off. Workers include: engineer, geologist, company representative, tool pusher, mud loggers (2).
   3) In extreme terrain or remote locations, company may put up camps at drill site. Additional buildings (portable) for sleeping quarters and cooking and eating are used. Camp crew includes cook, assistant cook. Support facilities include septic systems, refrigerated food storage. Camp jobs eliminate some traffic due to shift changes.

3. Support Services/Vehicles: Water supplier, several trips per day (fresh water required to drill through all fresh water aquifers ranging from 600 ft to 2500 ft below surface at rate of 10 bbl per ft).
   About 40,000 bbls of water required to drill remainder of well unless lost circulation problems occur, then more water required. A separate water truck may make 2-3 trips per day to spray fresh water on roads for dust control. Water source well is usually drilled for rank wildcat wells.
   Mud supplier - 1 trip per week
   Cement supplier - 3 or more trips per well (to set surface casing, intermediate casing, and to plug well when abandoned or set production casing).

Mud engineer - 1 trip per day
Tool supplier - 2 trips per week
Electric logger - 2 trips per well (2-3 person crew and rig to log well, usually after intermediate casing string is set and again after total depth is reached).
Drill stem tester - 1 trip per formation (1-2 person crew; may be 8 or more tests per well).
Safety engineer - on location when drilling out bottom of surface casing (600-1000 ft) and also acts as security for the location through end of drilling (2 men per rig, 12 hr shifts).
Blow-out prevention equipment tester - 1-2 trips per well minimum, and at least once per month on longer operations.
State Board of Oil and Gas inspector - 1 trip per well

Length of Operation: 60-365 days

5. Size of Site: 4-5 acres (variables include distance from suppliers and need for more storage space, size of rig, size of reserve pit)

6. Reserve Pit Construction: Average 125 ftx200 ft and 12 ft deep. Generally lined with 8-10 mil reinforced nylon/plastic. Location fixed by rig location.

7. Site Preparation & Construction: Dirt work contractor, usually 3-man crew, for 1 week. Equipment includes 2 scrapers (627 push/pull), 2 D-8 caterpillars, and 1 motor patrol grader)

8. Access Roads: Length - typically 1 to 5 miles
Quality - 18 ft wide crowned and graveled with ditches and turnouts. Uses about 2.2 acres per mile of land; culverts added if drainages must be crossed, but operators usually will lengthen road to avoid drainages to minimize maintenance and to maintain maximum grade of 10% or less.

9. Hazards: Drilling: Hydrogen sulfide may damage equipment, lost circulation, and high water flows; drilling difficult due to steep dip/crooked holes can result
Environmental: Hydrogen sulfide vehicle accidents and associated spills enroute

10. Reclamation: Dry holes: assume plugging per BOGC rules and revegetation to quality of surrounding area; stockpiling of topsoil not required, but is typically done; water is left to evaporate in reserve pit. After fluid has evaporated, liner is folded over the top and pit filled in, recontoured, topsoil replaced. Seeding is BLM, State Lands, ASCS, or private

landowner's specification. Trees may be planted in forested areas.

PRODUCTION

Average Field Size: 2-3 wells capable of yielding 400-500 bbls per day would be economic minimum target (1 million barrels of oil reserves). Possible overthrust field could be over 100 million barrels (a giant field).

2. Well Completion: 1) Casing crew (2-3 persons) arrives with 2-3 truck loads of casing; the drilling rig is typically used to set the casing (see Chapter 2 text for description of casing, perforating, formation fracturing, and other well completion procedures). A completion rig (smaller in size) is used to complete well for production.

3. Associated Gas: Volume - average of 300-500 mcf per day per well. "Casinghead" gas may be flared in volumes up to 100,000 cubic feet (mcf) per day. If volumes exceed 100,000 cf per day, operator must demonstrate there are not economical alternatives to flaring and receive BOGC approval to flare greater volumes. If this gas is sold, it is transported in buried, 4-inch low-pressure gathering pipe, usually no more than 3-5 miles in length, that is connected to 6-inch pipe and sent to a gas treatment plant for removal of liquids, contaminants, and for compression.

4. Oil Production: Volume: new wells typically produce 300-500 barrels per day and drop to about 60-70 bbl per day at economic cutoff. Average life-span is 8-10 years. New wells usually flow without a pump for up to 4 years. Winters can prevent transport of oil at times; therefore, storage capacity is higher, usually 8-10 days production.

Surface facilities: single leases are average of 1 section and could support 2 wells, assuming statewide spacing of 320 acres per well. Both wells may use 1 tank battery which doubles the size of surface facilities. The surface facilities can include: pumping unit with an electric or natural gas engine; tank battery situated away from well and consists of 3-5 oil tanks (1000 bbls capacity); and a heater treater. Due to fire safety consideration, well head, heater treater, and tanks are separated by about 150 ft. Tanks are usually 16 ft high x 24 ft in diameter. Heater treater is 27 ft high x 8 ft diameter. Pump is usually 30 ft long and 20 ft high. A dirt dike 3 ft high is placed around tanks to contain spills.

Transportation: oil is typically trucked away in tankers (200 bbl capacity) at a rate of 15 loads per week per well.

Traffic volume: well is visited daily to ensure equipment is operating properly. Snow removal from September to May may require daily use of snow blower, a caterpillar, and a motor grader.

Crew size: a field of 8-10 wells typically requires a 4-person crew--foreman, pumper, and 2 maintenance persons.

5. Gas Production/Gas Condensate (light oil):

Volume: ranges from low end 500,000 cubic feet per day with 50 barrels condensate to 10 million cf per day with 1,000 bbls condensate. Life of wells - 10 to 30 years. Content of gas may very. Gas sweetening may be required in order to market gas. Must have volume of 50-100 million cf per day of gas to build a plant for recovery of sulfur and sweeten gas.

Facilities: well head (big wells rated at 5,000-8,000 psi) gas separator (for low condensate well - 6 ft x 15 ft, for big well 3 stages to drop pressure 2 ft x 15 ft high), meter shack 6 ft x 8 ft, vapor recovery shed 10 ft x 10 ft, 8-10 days oil storage capacity--probably 3-5 2,000 barrel tanks 30 ft x 27 ft for big well; 2 400 barrel tanks for small well 12 ft x 20 ft; 3 ft berm (earthen) built around tanks 40 ft x 70 ft to contain spills (1,500 barrel capacity).

Transportation: probable truck transport of oil. 5 trucks per day for a big well, 1 truck every 4 days for small well. Gas must have a pipeline. Big wells flowing 10 million cf per day at 500 to 1,000 psi would use a 6-inch to 8-inch high press line, but a low-end well would use a 4-inch line with a pressure of 200 psi.

Large field development would soon warrant pipeline transport of oil plus sulphur plant with dry gas as product sweetened for sale to utility.

Crew size: same as oil for equal size field.

6. Reclamation: Wells are permanently plugged with cement across all important zones and at the surface. A steel plate is welded onto the top of casing, and well marker is left to designate the well location. All equipment is removed, site is graded with cat, and topsoil is replaced with scrapers and bladed with motor grader back to near original contours. Topsoil is disced and seeded according to landowner's request, usually as per BLM or state specifications. Vegetation must be healthy and successful before reclamation bond is released. Abandoned well marker may be installed or cut off below plow depth. Forested areas may require tree planting.

DISTRICT: NORTHERN MONTANA (SWEETGRASS ARCH - BEARPAW UPLIFT)

MAXIMUM COMMON WELL DEPTH: 3,500 - Cut Bank Formation (oil)
1,600 - Eagle Formation (gas)

PRODUCTS:
1) Oil predominates in western part (Cut Bank and Kevin-Sunburst area
2) Gas in eastern portion (Tiger Ridge - Bowdoin areas)

DRILLING:

1. Rig Size/Type:

OIL	GAS
Double derrick, jack-knife	Single derrick, drive-in
Diesel engines (2)	Diesel engine (2)
Weight: 350,000 lbs per load	Weight: 80,000 lbs
Height: 110 ft with substructure	Height: 70 ft with substructure
Total horsepower: 800 hp	Total horsepower: 350 hp
Loads to move: 7 at 45,000 lbs per load	Loads to move: 4-5 units at 45,000 lbs per load

2. Crew Size:

OIL	GAS
4 man rig crew	3 man rig crew
Support crew: toolpusher geologist	Support crew: toolpusher geologist

3. Support - Service/Vehicles:

OIL - Water truck - trips necessary to supply about 3,000 bbls fresh water.
Mud supplier - 1 or 2 trips per well
Cement trucks - 2 trips per well
Mud engineer - n/a; mud maintained by crew
Tools (bits) - 1 trip per well
Loggers - 1 trip per well
Tester - 2 trips per well
Safety engineer - n/a; no hydrogen sulfide
BPO tester - n/a; blow-out preventors tested with rig pump

GAS - Water truck - trips needed to supply 1500 bbls fresh water.
Mud supplier - 1 trip per well
Cement trucks - none; rig brings cement and has cementing pump
Mud engineer - n/a; mud maintained by rig crew
Tools (bits) - 1 trip or less per well
Loggers - 1 trip per well
Tester - 3 trips per well maximum
Safety engineer - n/a; no hydrogen sulfide
BPO tester - n/a; test with rig pump

4. Length of Operation:

OIL	GAS
7 days average	48 hours average

5. Size of Site:

OIL	GAS
1 acre	1/2 acre

6. Reserve Pit Construction:

OIL
reserve pit: 50 ft x 100 ft, 6 ft deep
earthen working pit: 20 ft x 100 ft, 4 ft deep
liner: not required

GAS
reserve pit: not constructed
working pits: 3 earthen pits, 10 ft x 25 ft, 6 ft deep
liner: not required

7. Site Preparation and Construction:

8. Access Requirements: 12-16 ft bladed trail (1.5 acres per mile), length 1/2 mile or less, drainage crossings avoided.

(NOTE: Access roads are not built for many gas wells in this area; the rig is driven to the site. If the site is sufficiently level, only the pits will be dug.)

9. Hazards: Drilling - occasional lost circulation

10. Reclamation: Dry hole: hole plugged or bottom portion plugged and surface portion given to landowner for water well. Pit allowed to dry out and location backfilled and recontoured. Topsoil replaced if stockpiled, reseed to meet landowner's wishes.

PRODUCTION

1. Average Field Size:

OIL
3-5 wells (common well density - 1 per 40 acres)

GAS
3-10 wells (common well density - 1 well per section, 640-acre spacing)

2. Well Completion: 1) Rig crew rungs casing. Surface casing - 1 truck load (partial load); production casing - 1 partial load. Surface casing is often brought to the well with the rig and would be included in one of the rig loads.

3. Associated Gas: Oil wells produce very little gas, the available gas is usually used as lease fuel, virtually none is available for sale.

4. Oil Production: New oil wells produce about 20-50 bbls per day, declining to 10 bbls per day within 6 months to 1 year. Life span 10-20 years.

Surface facilities:
- pumping unit with electric motor or propane-fueled engine. Tank battery includes 2 or 3 oil tanks, heater-treater, and/or gun barrel.

Transportation:
- Oil from remote wells/small fields is trucked. Oil pipelines carry oil from larger existing fields.

Traffic:
- oil wells visited daily by pumper.

5. Gas Production: Gas wells produce sweet, dry gas nearly 100% methane. New gas wells produce about 100-500 MCF per day. Gas production is highly dependent on market demand and pipeline pressure. Life: 5-20 years.

Surface facilities:
- wellhead and meter house (4 ft x 6 ft metal shed).

Transportation:
- Gas is gathered with 3-6 inch plastic or steel-buried lines connecting wells to compressor. Gas is compressed into 6-10 inch main gas line. Major lines are Montana Power, MDU, and Northern Natural Gas.

Traffic:
- gas wells visited weekly to change meter chart.

6. <u>Reclamation</u>: Exhausted wells are plugged, surface equipment removed, concrete pumping unit bases removed or buried, and site reseeded to landowner specifications. Buried gas lines are often abandoned in place.

"TYPICAL WELL" FACT SHEETS

DISTRICT: NORTHEASTERN MONTANA (WILLISTON BASIN)

MAXIMUM COMMON WELL DEPTH: 12,000 FT - Red River Formation

PRODUCTS: Oil with associated gas

DRILLING:

1. Rig Size/Type: Triple derrick, jack-knife type
   Diesel or diesel-electric
   Weight: about 1,500,000 pounds
   Height: 150 ft (assuming 20 ft substructure)
   Engine: about total 900-1100 horsepower from 3 engines
   Requires 33 one-way truck loads to move rig to the site

2. Crew Size:
   1) Rig crew - 4-5 persons on the rig per shift (shift 8 hours; 3 shifts per day)
   2) Support crew per shift: mud loggers, engineer, geologist, company representative

3. Support Service/Vehicles: Water supplier - several trips per day (fresh water (5000 bbls) required to drill through all fresh water aquifers ranging from 600-2500 ft below surface (at rate of 10 bbl per ft.) (about 12,000-15,000 bbls of salt water required to drill remainder of the well); a separate water truck may make 2-3 trips per day to spray fresh water on roads for dust control.
   Mud supplier - 1 trip per week
   Cement supplier - 2 trips per well (to set surface casing and plug well when abandoned).
   Mud engineer - 1 trip per day
   Tool supplier - 2 trips per well
   Electric loggers - 1 trip per well (2-3 person crew and rig).
   Drill stem tester - 1 trip per formation (2-3 person crew - may be 8 tests per well maximum, less near producing wells).
   Safety engineer - (arrives when 1000 ft above Mississippian Formation, stays to end of drilling).
   State inspector - one trip per well

4. Length of Operation: 45-60 days

5. Size of Site: 4-5 acres (variables include distance from suppliers and need for more storage space, size of rig, size of reserve pit)

6. Reserve Pit Construction: 100 ft x 180 ft, 12 ft deep
Generally lined with 8-10 mill reinforced nylon/plastic
Location fixed by rig location

7. Site Preparation and Construction:

8. Access Roads: Length: typically 1 mile or less
Quality: 12-16 ft-wide bladed trail (topsoil left, vegetation scraped); uses about 1.5 acres per mile of land; culverts added if drainage must be crossed, but operators usually will lengthen road to avoid drainages to minimize maintenance.

9. Hazards: Drilling: Hydrogen sulfide may damage equipment
Environmental: Hydrogen sulfide and salt water

Reclamation: Dry holes: assume plugging per BOGC rules and revegetation to quality or surrounding area; stockpiling of topsoil not required; but is typically done; water (containing 125 lbs salt per barrel) is typically pumped from reserve pits and trucked to disposal wells; pit is left open for remaining fluid to evaporate, then liner is folded over the top and pit filled in, recontoured, topsoil replaced.

Reclamation following successful well: site is reclaimed as above except well is left intact, production facility is constructed, and either truck turn-around or pipeline is installed to transport hydrocarbons away. Location is reduced from 5 to 2 acres.

PRODUCTION

1. Average Field Size: 2-3 wells (maximum density is 1 per 160 acres; typical is 1 well per 320 acres)

2. Well Completion: 1) Casing crew: (2-3 persons) arrives with 2-3 truckloads of surface casing; the drilling rig is typically used to set the casing (see Chapter 2 text for description of casing, perforating, formation fracturing, and other well completion procedures); 6-7 truck loads of production casing

2) Completion Rig: truck mounted, telescoping derrick
   weighs 60-70,000 lbs
   Capacity - 150,000 lbs
   Crew Size - 4 men plus tool pusher or company man, safety engineer also
   2-3 weeks to complete

3. <u>Associated Gas</u>: Volume: average of 70 mcf per day per well. "Casinghead" gas may be flared in volumes up to 100,000 cubic feet (cf) per day. If volumes exceed 100,000 cf per day, operator must demonstrate there are not economical alternatives to flaring and receive BOGC approval to flare greater volumes. If this gas is produced/sold, it is transported in buried 2-3 inch low-pressure gathering pipe, usually no more than 3-5 miles in length, that is connected to 8-12 inch steel pipe and sent to a gas treatment plant.

4. <u>Oil Production</u>: Volume: new wells typically produce several hundred barrels per day for up to 2 years and thereafter drop to about 60 barrels per day. Average life span is 18 years.

Surface facilities: pumping unit with an electric or natural gas engine; tank battery situated about 125 ft from the well and consisting of 1 salt water tank, 3 oil tanks (500 barrel capacity), and heater treater. Tanks are variable but 15-20 ft high and 15 ft in diameter.

Transportation: oil is typically trucked away in tankers (200 barrel capacity) at a rate of 2-3 loads per week.

Traffic volume: well is visited daily to ensure equipment is operating properly.

Crew size: 1 pumper

DISTRICT: CENTRAL MONTANA (BIG SNOWY UPLIFT)

MAXIMUM COMMON WELL DEPTH: 5,000 - Tyler Formation

PRODUCTS: Oil and very small quantities of associated gas

DRILLING:

1. Rig Size/Type: Double derrick, jack-knife
   Diesel engines (2)
   Weight: 650,000 lbs per load
   Height: 135 ft with substructure
   Total horsepower: 800 hp
   Loads to move: 14

2. Crew Size:
   1) Rig crew: 4-man crew per tour (shift 8 hours; 3 shifts per day)
   2) Other crew: toolpusher, geologist

3. Support - Service/Vehicles: Water truck - trips necessary to supply about 5,000 bbls fresh water.
   Mud supplier - 1 trip per well
   Cement trucks - 2 trips per well
   Mud engineer - n/a; mud maintained by crew
   Tools (bits) - less than 1 trip per well; rig brings bits for about 3 wells
   Loggers - 1 trip per well
   Tester - 2 trips per well
   Safety engineer - n/a; no hydrogen sulfide
   BOP tester - n/a; blow-out preventors tested with rig pump

4. Length of Operation: 10 days average

5. Size of Site: 2 acres

6. Reserve Pit Construction: Reserve pit - 50 ft x 100 ft, 6 ft deep
   Earthen working pit - 20 ft x 100 ft, 4 ft deep
   Liner - not required (fresh water system)

7. Site Preparation and Construction:

8. Access Roads: 12-16 ft bladed trail (1.5 acres per mile), length 1 mile or less, drainage crossings avoided

9. Hazards: Water flows near mountains, waterflood projects. Water is fresh. Occasional lost circulation.

10. Reclamation: Hole plugged or bottom portion plugged and surface portion given to landowner for water well. Pit allowed to dry out and location backfilled and recontoured. Topsoil replaced if stockpiled, reseed to meet landowner's wishes.

PRODUCTION:

1. Average Field Size: 1-5 wells (common well density - 1 per 40 acres)

2. Well Completion: 1) Rig crew runs casing. Surface casing - 1 truck load (partial load); production casing - 1 full load and 1 partial load.

3. Associated Gas: Wells produce very little gas; the available gas is usually used as lease fuel, virtually none is available for sale.

4. Oil Production: New oil wells produce about 50-100 bbls per day, declining to 20 bbl per day within 6 months to 1 year.

   Surface facilities: pumping unit with electric motor or propane-fueled engine. Tank battery includes 2 or 3 oil tanks, heater-treater, and/or gun barrel.

   Transportation: Oil from remote wells/small fields is trucked. Oil pipelines carry oil from larger existing fields.

   Traffic: Well visited daily by pumper.

5. Reclamation: Exhausted wells are plugged, surface equipment removed, concrete pumping unit bases removed or buried, and site reseeded to landowner's specifications.

DISTRICT: SOUTHCENTRAL MONTANA (BIG HORN BASIN)

MAXIMUM COMMON WELL DEPTH: 7,000 - Tensleep

PRODUCTS: Oil
A few small gas fields

DRILLING:

1. Rig Size/Type: Triple derrick, jack-knife
Diesel engines (3)
Weight: 750,000 lbs per load
Height: 151 ft with substructure
Total horsepower: 800-1000 hp
Loads to move: 15-20 at 45,000 lbs per load

2. Crew Size: 1) 4-man crew per tour (shift)
2) Other crew - toolpusher, geologist

3. Support Service/Vehicles: Water truck - trips necessary to supply about 7,000-9,000 bbls fresh water
Mud supplier - 1 trip per well
Cement trucks - 2 trips per well
Mud engineer - once per 3 days
Tools (bits) - less than 2 trips per well
Loggers - 1 trip per well
Tester - 3 trips per well
Safety engineer - 1000 ft above Phosphoria formation
BPO tester - n/a; blow-out preventors tested with rig pump

4. Length of Operation: 15-20 days average

5. Size of Site: 2-3 acres

6. Reserve Pit Construction: Reserve pit - 75 ft x 100 ft, 9 ft deep
Liner - not required (fresh water system)

7. Site Preparation and Construction:

8. Access Roads: 12-16 ft bladed trail (1.5 acres per mile), length 1 mile, drainage crossings avoided.

9. Hazards: Drilling: occasional lost circulation; some hydrogen sulfide in deeper formations, primarily Phosphoria and Madison. Some crooked hole problems.

10. Reclamation: Dry hole: Hole plugged or bottom portion plugged and surface portion given to landowner for water well. Pit allowed to dry out and location backfilled and recontoured.

Topsoil replaced if stockpiled, reseed to meet landowner's wishes.

PRODUCTION:

1. Average Field Size: Oil - 2-5 wells (common well density - 1 per 40 acres). Dry Creek field is only significant gas production.

2. Well Completion: 1) Rig crew: runs surface casing if less than 250-300 ft; casing crew if more surface casing required. Surface casing - 1 truck load; production casing - 1 full load and 1 partial load.

3. Associated Gas: Oil wells produce very little gas; the available gas is usually used as lease fuel, virtually none is available for sale.

4. Oil Production: New oil wells produce about 50-150 bbls per day, declining to 20-40 bbls per day within 6 months to 1 year.

   Surface facilities: pumping unit with electric motor or gas-fueled engine. Tank battery includes 2 or 3 oil tanks, heater-treater, and/or gun barrel. Major fields (Elk Basin) may have a few large consolidated batteries.

   Transportation: oil from remote wells/small fields is trucked. Oil pipelines carry oil from larger existing fields.

   Traffic: oil well visited daily by pumper.

5. Gas Production: Gas wells produce 500-1000 MCF per day, gathered in field and compressed into major pipeline. Field lines are about 2-4 inch diameter buried steel; major lines (MDU and Montana power) are 10 inch buried steel.

   Gas facilities: wellhead and meter house.

   Gas wells visited weekly.

6. Reclamation: Exhausted wells are plugged, surface equipment removed, concrete pumping unit bases removed or buried, and site reseeded to landowner's specifications.

DISTRICT: SOUTHEASTERN MONTANA (POWDER RIVER BASIN)

MAXIMUM COMMON WELL DEPTH: 7,500 - Minnelusa

PRODUCTS: Oil
Few small gas fields

DRILLING:

1. Size/Type: Triple derrick, jack-knife
   Diesel engines (3)
   Weight: 800,000 lbs per load
   Height: 151 ft with substructure
   Total horsepower: 800 hp
   Loads to move: 18 at 45,000 load
2. Crew Size: 1) Rig Crew - 4-man crew per tour (shift usually 8 hours, 3 shifts per day)
   2) Other crew - toolpusher, geologist

3. Support Service/Vehicles: Water truck - trips necessary to supply about 8,000-10,000 bbls fresh water
   Mud supplier - 1 trip per well
   Cement trucks - 2 trips per well
   Mud engineer - once per 3 days
   Tools (bits) - less than 2 trips per well
   Loggers - 1 trip per well
   Tester - 2 trips per well
   Safety engineer - n/a; no hydrogen sulfide
   BPO tester - n/a; blow-out preventors tested with rig pump

4. Length of Operation: 15 days average

5. Size of Site: 2-3 acres
6. Reserve Pit Construction: Reserve pit: 75 ft x 100 ft, 9 ft deep
   Liner: not required
   Mud is commonly native mud with few additives.

7. Site Preparation and Construction:

8. Access Roads: 12-16 ft bladed trail (1.5 acres per mile), length 1 mile or less, drainage crossings avoided.

9. Hazards: Drilling: occasional lost circulation.

10. Reclamation: Hole plugged or bottom portion plugged and surface portion given to landowner for water well. Pit allowed to dry out and location backfilled and recontoured. Topsoil replaced if stockpiled; reseed to meet landowner's wishes.

PRODUCTION:

1. Average Field Size:

OIL - 1-5 wells (common well density - 1 per 160 acres). Only one major field in area--Bell Creek--no Minnelusa production yet established; about 65 Minnelusa dry holes drilled in last 2 years. Secondary objective is muddy at about 5,000 ft.

GAS -

2. Well Completion: 1) Rig crew: runs surface casing if less than 250-300 ft; casing crew if more surface casing required. Surface casing - 1 truck load; production casing - 1 full load and 1 partial load.

3. Associated Gas: Oil wells produce very little gas; the available gas is usually used as lease fuel, virtually none is available for sale.

4. Oil Production: New oil wells produce about 100-150 bbls per day, declining to 40 bbls per day within 6 months to 1 year.

   Surface facilities: pumping unit with electric motor or gas-fueled engine. Tank battery includes 2 or 3 oil tanks, heater-treater, and/or gun barrel. Major fields may have a few large consolidated batteries.

   Transportation: oil from remote wells/small fields is trucked. Oil pipelines carry oil from larger existing fields.

   Traffic: well visited daily by pumper.

5. Gas Production: Gas wells produce 500-1000 MCF per day, gathered in field and compressed into major pipeline. Field lines are about 2-4 inch diameter buried steel; major lines (MDU and Montana power) are 10 inch buried steel.

   Gas facilities: wellhead and meter house.

   Gas wells visited weekly.

6. Reclamation: Exhausted wells are plugged, surface equipment removed, concrete pumping unit bases removed or buried, and site reseeded to landowner's specifications.

FACTORS INFLUENCING QUALITY OF PRODUCED WATER

Waters produced from a rock unit provide strong evidence of the depositional environment. In general, Cretaceous non-marine rocks, for example the Muddy formation, produce water with a fingerprint of the fluvial depositional environment while the Ordovician through Mississippian waters of the Williston Basin clearly reflect the basin margin and basin center evaporite sequence. Thick accumulations of anhydrite (anhydrous calcium sulfate - CaSO4, or gypsum without its water) result from cyclic changes in ancient sea levels or infusion of water into a subsiding basin. The ideal evaporite cycle and ideal evaporite basin are discussed by Krumbein and Sloss (1963).

The Williston Basin is a classic evaporite basin with evidence of both basin center and basin margin deposits. Through geologic time varying changes in inflow, erosion and deposits have affected the distribution of anhydrite in and around the Williston Basin. Wells in the basin produce water high in total dissolved solids (TDS). Total dissolved solids (TDS) is a measure of cations (Ca, Na, Mg, K) and anions (SO4, Cl and one half of HCO3). The driving constituents in anhydrite deposits are NaCl and CaSO4. Care is necessary in handling such brines because of their corrosive nature and high TDS concentrations mostly in the form of salts.

Evaporite deposits in the Williston Basin grade into dolomites and limestones to the west and the attendant improvement in produced water quality. Produced water can vary from very low TDS (in non-marine gas fields) to briney along the HiLine and in the Sweetgrass Arch area.

Central and south central Montana were affected by anhydrite deposition in the Mississippian period and as a result produced waters from deeper formations reflect this environment. The shallower non-marine Cretaceous rocks (sweetgas producers) produce slightly saline water.

ORIGIN AND OCCURRENCE OF HYDROGEN SULFIDE

Factors affecting the presence of hydrogen sulfide include the character of the source and/or reservoir rock, temperature of the hydrocarbon reservoir, and whether or not the hydrocarbon originated from marine source rocks. Anhydrite source or reservoir rocks (those containing gypsum) are the main contributors of hydrogen sulfide in concentrations over 5 percent (Werren 1985). It is believed that hydrocarbon source rocks which develop in non-marine environments generate low concentrations of hydrogen sulfide (if any) with hydrocarbons, while source rocks composed of sediments deposited in a marine type environment are more prone to generate hydrogen sulfide (and at greater concentrations) (Werren 1985).

Kerogen containing various amounts of sulfur is generated from organic-rich rocks which are subjected to high temperature and pressure due mainly to their depth of burial. The sulfur is transformed into a variety of sulfur-bearing organic compounds such as mercaptans, iron sulfide, and

sulfates such as gypsum. These compounds are further reduced under anaerobic conditions to hydrogen sulfide gas by bacterial action. Associated gas produced along with sour crude oil is not necessarily high in hydrogen sulfide gas since the formation processes are separate and specific. For example, pyrite is very stable and requires extended reaction time to change from pyrite to another elemental form. Even at high temperatures and pressures associated with oil and gas formation, only trace quantities of hydrogen sulfide are derived. High sulfur oils derived from sulfur-rich organic matter seldom contain more than 5 percent sulfur by weight. Complete conversion of the oil to gas gives a hydrogen sulfide content less than 5 percent by volume (Smith 1985).

Gas in a reservoir can be sweetened or badly soured by conditions in the reservoir rocks. Chemical reaction can sweeten gas containing hydrogen sulfide when the gas is exposed to iron compounds, particularly in shales and sandstones. Concentrations of hydrogen sulfide can be increased by biogenic and non-biogenic reaction with sulfate, thermal desulfurization of crude oil and subsequent biogenic conversion of produced sulfates, direct breakdown of kerogen into methane and hydrogen sulfide, as hydrocarbons react with anhydrite (from gypsum) and by thermal conversion of high sulfur crude oils into condensate and gases including hydrogen sulfide and methane. Injection of water containing sulfate into sweet gas and oil reservoirs has resulted in hydrogen sulfide concentration. Levels toxic to man in just a few years due to reaction of sulfate with sulfur reducing bacteria.

The Blackleaf/Knowlton fields on the eastern edge of the Disturbed Belt and involve Mississippian and Devonian reservoir rocks producing gas and associated hydrogen sulfide up to 0.58 percent from about 6,000 feet (Werren 1985). In comparison, the Waterton field yields gas with 15 percent hydrogen sulfide, also from Mississippian rocks, but from a depth of 11,000 feet. Both fields produce from thrust sheets that repeat layers of Paleozoic rocks in the same manner and are very similar in structural formation. The difference is that the Waterton field has a carbonate reservoir unit (Mississippian Turner Valley) overlain by the anhydritic units (Mt. Heath Formation) thrust into contact with the Devonian anhydritic carbonates in many thrust slices in the overthrust field (Werren 1985).

FORMATION PRESSURE

In most producing basins in Montana, the formation pressure at a given depth is estimated using a fresh water gradient (0.443 pounds per square inch per foot of depth). In salt water basins such as the Williston Basin, the anticipated formation pressure is estimated by using a salt water gradient of about 0.465 psi per foot.

Subnormal Pressures

Subnormal pressures are thought to occur because of continental uplift of sediments during regional mountain building eras. Such tectonic episodes lead to the fracturing and faulting of formations, and the release of excess formation pressure through the open channels to lower pressure formations, or to the surface. Uplifting of the rocks above the depositional sea level can result in subnormal pressures, and in Montana, rocks that lie above sea level are most often those which contain less than normal pressure. In areas of

continuous deposition where rock formations are largely continuous across the geologic basin, subnormal pressure can result from the depletion of formations through oil or gas production. The effects of pressure depletion can often be seen in and near producing fields. Northern Montana's Sweetgrass Arch is generally considered to be a subnormally pressured area.

Abnormal Pressure

Abnormal formation pressures are encountered in many parts of the world. In order to contain the abnormal pressure, a formation must be limited in areal extent and exhibit conditions that prevent escape of the formation fluids to lower pressure zones. In most areas, the abnormally pressured formation is overlain by thick layers of sand-shale rocks. It is commonly believed that undercompaction of these sands and shales lead to the higher pressure as the undercompacted rocks allow more of the weight of the rock to be supported by the pore pressure of the fluid than usual. In compacted rocks, the rock itself has more strength to support the overburden and less pressure is transmitted to the fluid in the pore space. As sedimentation occurs above the limited reservoir, the overburden pressure increases and since the formation fluids cannot be expelled, the pore pressure increases to support the overburden. The depositional environment in Montana is not commonly associated with abnormal pressure conditions. The U.S. Gulf Coast is the most extensively explored region of the country that exhibits abnormal formation pressures. Severe abnormal pressures also exist in France, Australia, and Canada; the highest abnormal pressures recorded have been in Iran.

Abnormal pressure in carbonate rock is less well defined than in clastics (sand and shale). Carbonates may be overpressured because of chemical diagenesis, mineral phase changes, or other reasons. As is the case for clastic rocks, however, the over pressure must be confined within a reservoir rock of limited extent. Such reservoirs might include reefs or bioherms which are physically isolated from the surrounding sediments. Continuous limestone and dolomite formations such as occur in Montana are much less likely to contain abnormal pressure. Very deep formations which are subjected to compression and distortion due to tectonic forces near mountain thrust faults may be over pressured as long as the overpressured rocks are sufficiently isolated to prevent pressure loss through fractures or faults to lower pressure formations. Such overpressured formations are encountered in Wyoming in very deep drilling near mountain ranges.

In the Lodgepole blowout, which occurred in Alberta, Canada October 1982, the drilling operation was targeting a Nisku stratigraphic reef of porous dolomite at about 3,000 meters in depth. The reservoir was overpressured and contained about 25 percent hydrogen sulfide. Further south, the control is a thrusting of evaporitic Mississippian and Devonian beds in the vast Waterton field with its attendant hydrogen sulfide concentration. South of Glacier Park and north of the Sawtooth Range, "a lateral shift separates Montana from the productive Canadian type of geology" (Fanshawe 1985). The potential for blowout under conditions similar to that at Lodgepole is not likely, based on present understanding of Montana's geologic history.

At Big Piney in Wyoming, the blowout occurred in a Madison reservoir at 15,700 feet. The reservoir is controlled by large scale basement structures

unaffected by subsequent thrust faulting (Werren 1985). The gas composition of 3 percent hydrogen sulfide, 70 percent carbon dioxide, 8 percent helium, and other inert gases and only 19 percent flammable gases with a bottom hole temperature (BHT) of 310 degrees Farenhiet suggests deep crustal degrading (Werren 1985).

Based on our understanding of the geologic picture in Montana from the Blackleaf Canyon well to the area near Bozeman, potential reservoirs would not involve thrusting of anhydritic units or deep basement fault-controlled units with extreme high pressure and high temperatures. West of the Overthrust/Disturbed Belt, exploration holes have encountered deep sections of Tertiary valley fill and Precambrian basement rocks, with occasional dikes or Tertiary intrusives. Based on present knowledge, these conditions are unlikely to contribute to the extreme overpressured reservoir environments encountered in Wyoming. However, given the unknowns, drilling along Montana's Overthrust should proceed with caution and assume a reasonable worst-case scenario. A more detailed discussion of blowout case studies can be found in Technical Appendix 5 - Health and Safety.

Table 2-1 cites examples of reservoir pressures for various fields in Montana.

GEOLOGIC CONSTRAINTS BY REGION

Region 1 - Overthrust and Disturbed Belt

Recent wildcat wells completed along the Rocky Mountain eastern front have provided a additional geologic information about the Montana Overthrust Belt but no oil or gas. The Montana portion of the Overthrust/Disturbed Belt extends southward in a wide band from the Canadian border north of Glacier Park down through Glacier, Pondera, Teton, Cascade, and Meagher counties, swinging west to Beaverhead County and then south out of the state. Madison County and parts of Beaverhead, Gallatin, and Park counties belong in the Rocky Mountain Foreland Province, a region dominated by Laramide basement-cored uplifts of Tertiary age and covered in part by Tertiary volcanics (Taylor and Ashely 1985).

Overthrust prospects usually aim for Mississippian or Devonian carbonate trap rocks at depths of 6,000 feet or greater. These rocks have yet to produce in the manner of rocks emplaced by the same mountain building forces in Alberta and Wyoming.

Drill sites in this region are often located on steep terrain with moderately difficult access requiring a substantial road system. Roads must be built to high standards to accommodate very large, heavy drilling equipment and vast amounts of support material for deep hole drilling. Drilling can be risky and difficult due to the complexity of the overthrust rock units, steeply dipping beds, and the unknown risk of hydrogen sulfide or other high pressure gases. Such drilling requires extensive mud-handling facilities with large lined reserve pits. Pit liners are absolutely necessary because the sites are usually near high-quality headwater streams and underlain by porous glacial, alluvial, or colluvial surface materials.

Table 2-1. Pressures for Various Fields in Montana.

Region	Field	Formation	Reservoir Pressure (psi) Actual	Calculated	Depth*	BHT (°F)
Region 1						
Overthrust/ Disturbed Belt	Blackleaf Canyon	Miss. Sun River				
		A	1500	1690	3900 (+1537)	118°
		B	800	2470	5700 (-200)	---
		Sun River East	1575	2180	5028 (-28)	---
Region 2						
Sweetgrass Arch	Cut Bank (gas)	Cret. Cut Bank	700-790	1270	2950-average depth to Cut Bank sands	79-85°
Bears Paw	Tiger Ridge	Cret. Eagle Cret. Judith River	380	693	1600' (+2900)	80°
Region 3						
Cedar Creek Anticline	Pennell	Silurian-Interlake	3870	3915	8420	198°
		Ord. Stony Mtn.	4035	4046	8700	200°
		Ord. Red River	4100	4092	8800	202°
Williston Basin	East Poplar	Miss. Charles '3'	2900-3000	2643	5684	248°
Region 4						
Central MT	Sumatra	Penn. Amsden	>1865	1732	4000 (-1000)	>163°
		Penn. Tyler	"	2035	4700 (-1700)	"
	Big Coulee	Cret. Frontier	635	736	1700 (+2500)	---
		Cret. Lakota	1100	866	2000 (+2200)	---
		Jur. Morrison	---	953	2200 (+2000)	98°
Region 5						
South Central	Rapelje	Cret. Judith River	---	240	550 (+3470)	> 65°
		" Claggett	---	325	750 (+3270)	"
		" Eagle	>560	476	1100 (+2920)	> 95°
		" Virgelle	"	541	1250 (+2770)	"
Big Horn Basin	Elk Basin	Cret. Frontier	500-600	563	1300 (+3200)	80°
		" Greybull	1240	1040	2400 (+2225)	90°
		Penn. Tensleep	2234	1300-2800	3000-6500 (+640-1600)	120°
		Miss. Madison	2264	1862-2800	4300-6500 (+250-1400)	125°
		Dev. Jefferson	2132	2295-2790	5300-6490 (-750-1500)	135°
Region 6						
Powder River Basin	Belle Creek	Cret. Muddy	1190	1950	4500 (-700)	103°

* Indicates formation elevation above or below mean sea level.

Source: Compiled by Earl Griffith, DNRC, based on data contained in Montana Geological Society 1985.

Although over 40 holes have been drilled (some over 13,000 feet), the only production is from the Two Medicine-East Glacier field in the thrust and fold belt and the Blackleaf-Knowlton field on the east edge of the Disturbed Belt. Neither is the magnitude of fields in similar terrain in southern Alberta. This may be due to a lateral shift in structural form from the productive Canadian type of geology (Fanshawe 1985). In fact, the Waterton field derives production from thrusted dolomitic Mississippian and Devonian units around 11,000 feet. Equivalent porous reservoir rocks have not been found along the Overthrust and Disturbed Belt in Montana despite numerous holes west of the limit of thrusting. Related to but not included with the Overthrust/Disturbed Belt, the Tertiary Intermontane basins (west of the thrust belt) and Foreland Province of Basement (Archeau) rocks also have not proven productive.

The Overthrust Belt extends south until interrupted by the Batholithic Province of Cretaceous Tertiary time in the vicinity of Helena. South of the batholithic province in Beaverhead County, the overthrust drilling has given minor shows but no production. Projection of the overthrust feature across Idaho's Snake River Plain has not been successful (Fanshawe 1985). Areas west of the Thrust Belt that receive attention when drilling for oil and gas include the deep mountain basins. For a more detailed description of geologic provinces and oil potential, refer to papers by Lageson, Fanshawe, and Peterson in the 1985 Montana Oil and Gas Field Symposium (Montana Geological Society 1985).

Regions 2 and 3 - Hi-Line and Williston Basin

Region 2 and the north half of Region 3 were extensively glaciated by continental ice sheets. The Cretaceous rocks of the Montana and Colorado groups are mostly covered by a veneer of glacial debris, including permeable outwash gravels and till (a mixture of clay, silt, sand, and boulders) of varying permeability. Relatively little disturbance is required for drill sites and access roads because of the flat to rolling terrain and existing extensive road system.

Oil and gas production in Region 2 is primarily from Mississippian, Jurassic, and Cretaceous rocks at fairly shallow depths. Drilling is with fresh water and unlined pits. On occasion, brackish water (TDS of 3,000 to 10,000 ppm) is produced, but it is usually disposed of by injection to assist in recovery from these old fields.

Oil production in Region 2 is primarily from stratigraphic traps on the flanks of the Sweetgrass arch from Mississippian through Cretaceous units. Gas is produced in association with and independently of oil in the Sweetgrass area. To the east, most gas in Tiger Ridge and Boudoin fields is produced from Cretaceous units. Drilling depth ranges from 3,500-6,000 feet in the Sweetgrass area and from 1,500 to 3,500 in the Bears Paw area. Produced water can run from less than 3,000 ppm TDS to over 20,000 ppm TDS in Sweetgrass fields where pits are generally not lined. Sour gas is encountered here and most oils from the area contain 1 to 2 percent sulfur.

Bears Paw produced water is generally salty, ranging from fresh to over 10,000 ppm TDS. Gas produced out of the Cretaceous is sweet.

Domestic and livestock water supplies come from shallow wells in the glacial aquifers. Farther east, water is taken from the Fox Hills and Hell Creek formations. Where these units are extensively used as a water source, surface casing in oil and gas wells is placed at least 50 feet into the underlying Bearpaw shale.

Region 3 produces nearly 70 percent of the state's oil, primarily from Ordovician through Mississippian carbonate rocks of the Williston Basin and Cedar Creek Anticline. The Williston Basin proper is an example of a classic subsiding basin with evaporite deposits (rock composed of minerals produced from a concentrated saline solution, usually containing arehydrite and halite (NaCl, limestone and dolomite) found at the basin center (upper Charles Formation) and at the margin (lower Charles Formation) (Krumbein and Sloss 1963). The presence of these evaporite deposits gives rise to hydrogen sulfide and very briney waters. Hydrogen sulfide up to 30 percent has been encountered and produced water ranges from 50,000 to 300,000 ppm TDS. Bottom hole pressures can run up to 6,000 psi in holes 13,000 feet deep.

The same units produce on the Cedar Creek Anticline as in the Williston Basin. Hydrogen sulfide is associated with the hydrocarbons in the Cedar Creek Anticline. Produced water runs as high as 300,000 ppm TDS, and bottom hole pressure runs up to 4,000 psi in holes 10,000 feet deep.

Carefully constructed and lined reserve pits are essential in the glaciated northern part of the Williston Basin. South of the limit of glaciation, the fine-grained units of the Fort Union Formation are less susceptible to shallow groundwater contamination. This does not mean, however, that reserve pits can be constructed to any lesser standard. With the fine-grained nature of the bedrock comes the attendant problem of a greatly reduced water supply in poorer quality than is found in the glaciated areas.

Region 4 - Central Montana

Unglaciated central Montana produces oil and gas from relatively shallow Cretaceous and Jurassic formations and oil from the Mississippian Big Snow Group and Pennsylvanian Amsden Formation. Maximum depth rarely exceeds 6000 feet with no hydrogen sulfide or saline water problems. Most oil is produced from structural traps on the Cat Creek and Sumatra anticlines and the Porcupine Dome. Gas production is confined to the broad synclinal structure of Big Coulee.

Central Montana produces oil and gas from relatively shallow Cretaceous and Jurassic formations and oil from the Mississippian Big Snowy Group and Pennsylvanian Amsden Formation. Maximum depth rarely exceeds 6000 feet with no hydrogen sulfide or saline water. Produced water from the Sumatra runs up to 17,000 ppm TDS. Most oil is produced from structural traps on the Cat Creek and Sumatra anticlines and the Porcupine Dome. Gas production is confined to the broad synclinal structure of Big Coulee. Produced water is either reinjected into the Madison (Sumatra) or used for secondary recovery waterflooding (Cat Creek, Sumatra, and several smaller fields).

Drilling and production are not topographically or geologically constrained in this area of flat to rolling terrain and straightforward

geology. Produced water is either reinjected into the Madison (Sumatra) or used for secondary recovery waterflooding (Cat Creek, Sumatra, and several smaller fields).

Region 5 - Big Horn Basin

As delineated, Region 5 includes the Big Horn Basin (Dry Creek, Elk Basin, and Franne) oil and gas fields, the gas-producing Lake Basin Fault Zone in Stillwater County, and several small oil and gas fields in Big Horn County associated with the Powder River Basin. Elk Basin produces oil from the Ordovician Bighorn Formation up through the upper Cretaceous Frontier Formation. Hydrogen sulfide up to 6 percent is encountered in both the Mississippian Madison and overlying Permian Phosphoria while the intervening Pennsylvanian Tensleep and Garwin formations are hydrogen sulfide free. The western Powder River oil fields produce from the Madison and Minnelusa formations with the Hardin gas field producing from the upper Colorado Group. Shallow upper Cretaceous units are the traps from the Lake Basin gas fields.

Drilling occasionally encounters lost circulation or crooked hole problems in the deeper holes of Elk Basin. Terrain and surficial geology generally do not constrain development. Unlined reserve pits are used here because of fresh water drilling. Dry holes are often plugged off and converted to a water well for use by the surface owner.

Region 6 - North Powder River Basin

Oil is produced from the Cretaceous Muddy Formation in the prolific Bell Creek field. In the Hammond field, gas is taken from Cretaceous rocks ranging from Skull Creek through Telegraph Creek formations. Attempts at oil production from the Minnelusa (7,500 feet) have not yet been successful. Drilling uses fresh water and native muds without any hydrogen sulfide or saline water problems. Some secondary recovery uses waterflooding from a Madison supply. Occasional losses of circulation are the primary drilling constraint.

The foothills terrain near Belle Creek founded on upper Cretaceous sandstone and shale has not presented any problem to site selection or access roads. Further east in the Hammond area, the surficial unit is a thick marine shale, the Pierre. Site and road construction on this shale unit can be extremely problematic, especially during wet periods. Overlying the Pierre west of Hammond are the critical groundwater aquifers of the Hell Creek and Fox Hills formations.

SOILS AND SOIL CONSTRAINTS IN THE OIL AND GAS REGIONS

Introduction

Montana has a vast array of different soil types. Parent material, along with climate, vegetation, relief, and time, are the five soil-forming factors (Brady 1972). The Soil Conservation Service in cooperation with the U.S. Forest Service, Montana Agricultural Experiment Station, and Montana State University produced a general soil map of Montana from which the following excellent explanation of soil formation has been taken.

Soil Formation in Montana

"Soils are unique natural bodies occurring on the earth's surface which contain living matter and support plant growth. The soils which we see and map are dynamic entities which are the results of an interaction between climate and organisms (plants and animals) acting on geologic parent material over time under conditions modified by local relief. These five agents are called the "soil forming factors"; they account for the many similarities and differences in the properties of the soils of the state. The relative importance of each factor in Montana are discussed below:

Parent Material: The complex geology of the Rocky Mountains coupled with the varied glacial history of the state present a wide range of parent materials from which soils have developed. Because of the relatively cool climate and short time period (in geologic terms) since major glaciation in Montana, many of the soils are very strongly influenced by the nature of the parent materials from which they have developed. Soil clay minerology, chemistry, and fertility are often predominately determined by parent material characteristics.

Climate: Precipitation in Montana varies from a low of 10 cm (4 in) annually to a high of 350 cm (140 in). Distribution of the precipitation by season is also highly variable and is further modified by local relief. These variations in precipitation are reflected in the soil moisture regime and in the vegetation. While soils in Montana all have generally cool mean annual temperatures, there are differences in summer soil temperatures which have affected soil development and are of practical importance in land use.

Vegetation: Montana has vegetation ranging from arid shrub and grasslands to lush coniferous forests. While the present vegetation occupying a particular site is influenced by soil properties, the development of the soil itself has been strongly influenced by the vegetational history of the site. Vegetation affects soil temperature and moisture through its influence upon ground cover, snow distribution, and transpiration. The marked contrast between well developed soils formed under adjacent forests and grasslands is a prime example of the effects of vegetation upon soil development.

Relief: The effect of local relief is to greatly modify regional climatic characteristics, presenting large differences in effective precipitation and soil temperature within a few meters of lateral distance. Slope steepness and slope position also have important influences on the stability of a site for soil development, and effects of slope aspect are often vividly pointed out by patterns of vegetation and snow distribution. The contrast in soil temperature, soil water, and vegetation on adjacent north and south facing slopes is particularly great in Montana and other latitude states.

Time: Soil formation is, by human standards, a time consuming process measured in hundreds and thousands of years. However, when measured by geologic time and compared to such geologic processes as mountain building, it is a relatively rapid and dynamic process. Because of its climatic, geologic and glacial history, Montana has no highly weathered soils such as occur in the tropics or even in southeastern United States. However, strongly developed soils with distinct horizons (layers) do occur in Montana on stable landscape position. On unstable sites such as active flood plains and steep slopes, soils remain "young" and weakly

developed for indefinite periods of time. On roadcuts, mine spoils, landslips, and small mounds of soil material exposed by treefall, soil formation is just beginning."

Major Kinds of Soil in Montana

Figure 2-1 tells better than words the complex story of soils in Montana. Each of the different patterns shown indicates one type of land area and the soils that predominate there. Each land area covers hundreds (or thousands) of acres, and besides the principal soil type, has others in smaller amounts. One field may have many different soils, depending on its slope, aspect, and when and how the soils were formed.

Montana's northern plains were covered by glaciers many thousands of years ago. The soils indicated on the map as "A" soils were all formed from glacial till - the material left as those glaciers receded. Most of this land area is arid to semiarid. The locations of the soil orders and their uses are explained below.

A1 - Mollisols are found on the rolling glacial till plains, and terraces or benchlands formed by glacial outwash. The western part has a small percentage of Aridisols on the clayey terraces, fans, benches, and the basins that were left by glacial lakes. Use: dryland farming and rangeland.

A2 - On the central till plains, Aridisols occur on the rolling plains, with Entisols and Aridisols in the hilly sections. Mollisols are found on the nearly level areas of the eastern portion. Use: dryland farming.

A3 - On the eastern glacial till plain, Mollisols and Entisols occur on the rolling plains, with Entisols dominating on the hilly sections. Use: dryland farming and rangeland.

The soils of the dry central plains of Montana occur over sedimentary bedrock. These soils are indicated on the map as "B" soils.

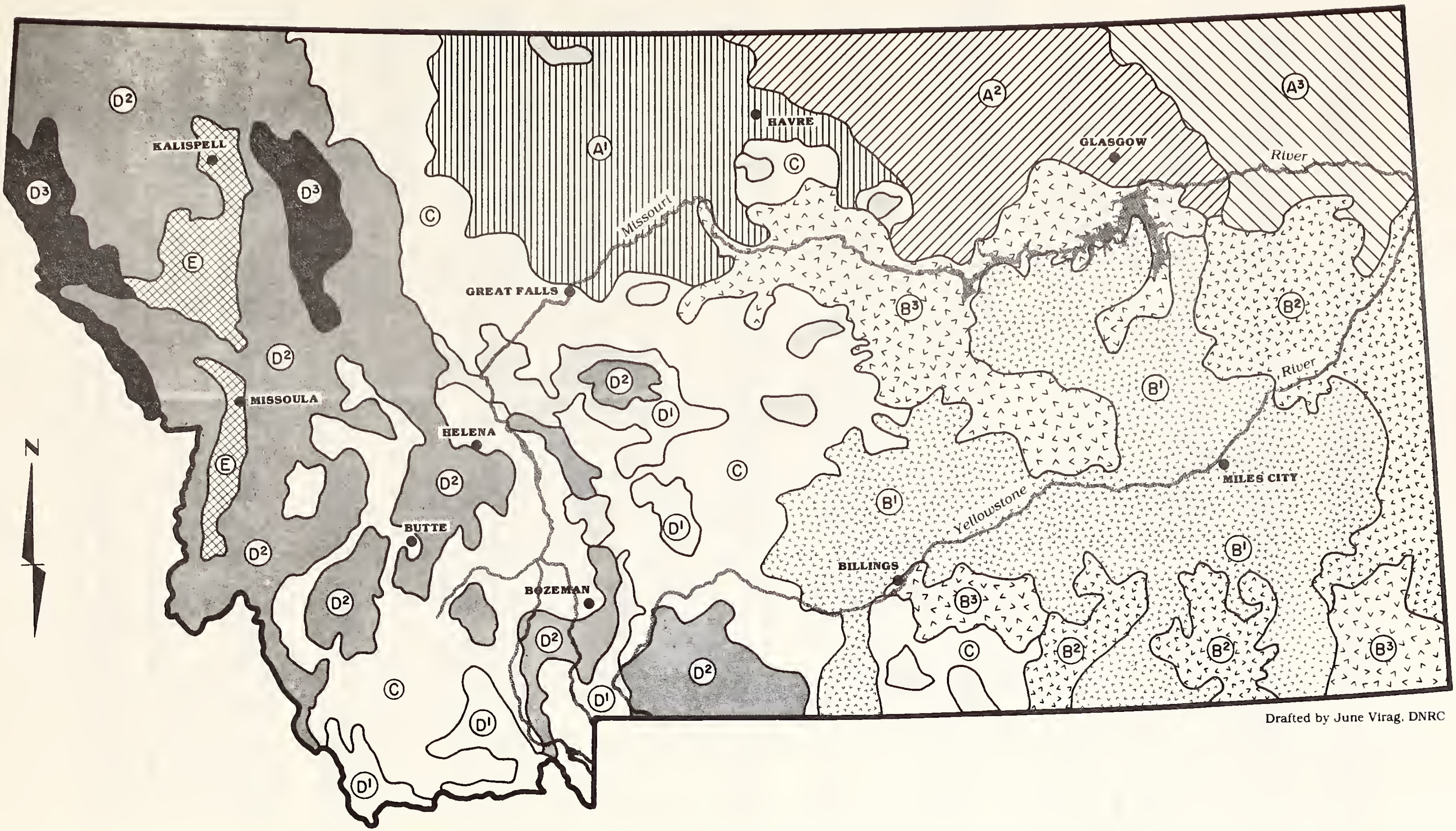
B1 - These plains and hills have "young' soils, the Entisols and Aridisols of the grasslands and shrublands. Some Mollisols are found in the western-most portion of this area. Use: rangeland, dryland farming.

B2 - Montana's southeastern plains have a semiarid to subhumid climate, and soils are Entisols, Mollisols, and Inceptisols on the Sedimentary bedrock plains and hills. On the gently sloping land forms, Mollisols are the major soils. Use: rangeland and dryland farming.

B3 - On the clayey-shale plains, soils are Entisols and Aridisols. This area also includes badlands and the steep slopes of the river "breaks" where Entisols predominate. Use: rangeland.

Mountain foothills, terraces, and benchlands with an arid to subhumid climate have soils indicated on the map as "C" soils.

C - Soils on the high foothills are mostly Mollisols, with some Inceptisols. On the lower foothills, benches, and terraces, the soils include



Drafted by June Virag, DNRC

Mollisols, Aridisols, and Entisols. The steep areas have mainly Aridisols and Entisols. Use: rangeland, with dryland farming on the gently sloping areas.

In Montana's mountains, soils of the open forest-grassland mingle with rocky outcrops and peaks. The climate is humid to subhumid. These soils are "D" orders.

D1 - On the steep forested mountains the soils are Inceptisols and Alfisols, with both Inceptisols and Mollisols on the open forested grasslands. Uses: timber, rangeland, watershed, and recreation.

D2 - In the humid forested mountains the soils are Inceptisols and Alfisols in the steep areas, and these soils occur on the valley and foothill moraines left by glaciers. Uses: timber, watershed, and recreation.

D3 - Mountain forest soils in the humid northwest are mostly Inceptisols with volcanic ash that accumulated there when ash drifted from volcanic action along the Pacific range in Washington and Oregon. These soils are unstable and erode easily. Uses: timber, watershed, and recreation.

The fifth of the five soil orders found in Montana are the "E" soils of the northwestern mountain valleys, where the climate is semiarid to humid, with warm dry summers and moist winters.

E - The mountain foothills, glacial moraines, and terraces contain Mollisols. On the drier terraces Aridisols are most common. Uses: orchards, rangelands, and crops.

Soils in Montana's Oil and Gas Regions

Region 1 - Overthrust/Disturbed Area: Soils developed on mountain foothills, terraces, and benchlands are often thin and overlie a wide variety of parent materials. Rapid permeability should be expected where such geologic conditions exist. However, much of the foothills region from Choteau to Browning consists of mixed glacial, fan, and terrace materials underlain by the Cretaceous Montana Group shale, sandstone, and siltstone. These erodible fine-grained subsoil materials are sensitive to disturbance and are important as a major repository of fossils.

Slope aspect will influence the vegetative types used in reclamation with north aspect slopes being cooler and wetter with much more organic material, while south aspect slopes are warmer, have less available soil moisture, and consequently are more difficult to reclaim.

Regions 2 and 3 - North Central/Williston Basin: Continental glaciation along the Hi-Line mixed the surface geological materials into a relatively homogenous soil parent material that evolved into a soil suitable for sustaining high quality range and small grain cropping. Soil permeability ranges from very slow in soils developed on shale to very rapid in soils developed in outwash gravels. The need for reserve pit liner integrity is essential, not only because of the varying permeabilities, but because of the near surface groundwater supplies. Areas of low permeability soils on shale bedrock where produced water is low in salt probably would not need a lined

pit, but areas with high permeability fill or outwash gravels would most certainly require a liner for slightly saline and greater salinity waters.

Reclamation throughout most of these two regions usually is not impaired by soil texture, slope, or climatic problems. There are some local areas of high clay soils (including bentonite) and badland soils which are erodible, easily impacted, and difficult to reclaim, but which are very suitable for unlined pits. These soils are, however, the least suitable for roads.

The south half of Region 3 includes a large area of steeply sloping terrain and soils developed on sedimentary shale and sandstone. The Cedar Creek area soils are predominantly clayey, having developed on uplifted sedimentary shale bedrock.

Region 4 - Central Montana: Drilling sites and access roads generally are located on level to strongly sloping terraces, benches, and alluvial fans along the axes of anticlines. The soils are highly erodible and predominantly clayey. Reclamation would be impaired by the high clay soil texture, steep slopes, and in the Big Breed Creek area, a natric (high sodium) horizon. Sodium, by itself, can be toxic to certain plants, but more importantly it disperses soil particles, reducing aeration and water infiltration, and it can chemically restrict accumulation of other critical elements in plant tissue (U.S. Department of Agriculture 1969).

Region 5 - Big Horn Basin/South Central Montana: Elk Creek, the major producing field, is located in an area of recently formed dry or shallow (aridic) soils on strongly dissected sedimentary bedrock. Dry Creek, east of Red Lodge, with the same soil conditions, has the added problem of slope failure in a shallow soil mass with a clay horizon or an entire slope mass underlain by a shale rock unit. Both development and reclamation are limited by these soil problems. The Lake Basin soils, by virtue of being in a topographic basin, are poorly developed, wet, and generally saline, all limiting to both development and reclamation.

Region 6 - Powder River Basin: Soils in the Bell Creek area are generally shallow, aridic, and are developed from sedimentary shales and sandstones in a rough, pine-covered foothills landscape. The clinker and sandstone-capped ridges, stable slopes, and moderate climatic conditions combine to create an environment that can be developed without serious problems and reclaimed with few natural constraints.

The Hammond Gas Field east of Bell Creek is in an area of high clay soils founded on shale bedrock. Soils have a limited moisture regime and are often sodic or contain large amounts of sulfate in essentially sterile surface soils. The clay content is very constraining to road construction and maintenance and to reclamation, especially when combined with the sodium or sulfate.

TYPICAL MITIGATION - HALL CREEK EXAMPLE

Road Construction

Road design specifications, construction standards, management requirements and maintenance needs were identified for the project using the operating limits of a heavy, extended length "lowboy" hauling a disassembled drill rig in an all-weather situation. A single-lane road 14-feet wide with turnouts and gravel surfacing was identified as the general road standard. The following measures summarize more specific information relating to Forest Service road standards found in a separate Project Transportation Analysis prepared for the well (Schaeffer 1984). These measures are illustrtive of the types of measures that can be developed on a case-by-case basis to mitigate potential adverse impacts associated with road and site construction in mountainous terrain.

a) Forest Service standard specifications for construction of roads and bridges, EM-7720-100, will be used for all road and bridge construction.

b) Road locations, design, and construction must reflect special efforts to assure the protection of the natural environment. This effort will be directed toward disposal of clearing slash, least practicable amount of excavation, erosion control during and after road construction, protection of natural drainage, protection of developed drainage, and other positive efforts that will contribute to a harmonious relationship between the road and its surroundings.

c) After the road project has been accepted by the Forest Service, the operator shall provide the Forest Service with a set of as-built plans.

d) Signing for roads will be determined by the Forest Service and the signs needed will meet the requirements and specifications set forth in the "Manual on Uniform Traffic Control Devices."

e) At any time the permittee elects to abandon a non-system road or the permit is terminated, or cancelled, all rights, title, and interests in the road on National Forest System Lands will be vested in the United States. At the time of abandonment, the Forest Service will review the facility in terms of management needs and purposes and the road will either be added to the National Forest Transportation System or obliterated and the disturbed area rehabilitated by the permittee.

f) The permittee is responsible for locating and protecting underground pipelines and powerlines.

g) Surface material sources will be agreed to with the Forest Service. Where the Forest Service agrees to provide a source, the permittee will develop a plan for development and rehabilitation of the pit.

h) Use of the road is not normally authorized until the permittee has completed all phases of road construction, except for revegetation.

The Forest Service may grant temporary use of the road based on substantial completion of road construction.

i) For road segments that will not be reclaimed, all earth cut or fill slopes favorable to revegetation or other areas on which ground cover is destroyed in the course of construction will be revegetated.

j) New borrow pits on the National Forest shall have topsoil stripped from the permitted area and be deposited in storage piles apart from other excavated material. After the desired amount of material has been removed, and the resulting pit has been trimmed and smoothed as required, the stored topsoil shall be evenly spread over exposed subsoil to the extent that may be practicable, and shall be revegetated.

If a new borrow pit cannot be located, soil in the existing East Glacier pit should be scraped off to a depth of 6-8 inches. Only material obtained below this depth should be used and plant growth on the road and pad should be strictly monitored.

k) All earth cut and fill slopes will be seeded with a grass mixture the first fall or spring following construction (whichever comes first). The seed mixture will be the same as that specified in the section on Road Reclamation (below).

l) Permanent bridges will be designed to accommodate a flood volume for a "50 year" flood. Because debris dams are the primary reason for bridge failure during flooding, approaches will be designed to allow flow to pass around the bridge structure. These design criteria are consistent with other designs in the District and experience during the 1964 and 1975 floods.

m) During operations, a turnaround with parking facilities will be constructed at the road closure location according to the authorized forest officer.

Pad Construction

Pad construction requirements and guidelines for the Hall Creek well were based upon information developed by the Forest Service in response to oil and gas developments in the forest. The guidelines, which are to be modified as needed, are contained in "Proposed Guidelines for Oil and Gas Development," (Hadley 1983). The following measures are examples of measures used to minimize impacts for site construction of the Hall Creek well.

a) The disturbed area is to be kept to the minimum necessary for drilling operations.

b) All available topsoil and excess material will be stockpiled at the wellsite area to be placed back on the site for rehabilitation.

c) Contour trenches shall be built to divert surface flow coming from slopes above the drillsite away from the drillsite.

d) The drill pad shall be designed to drain internally into the reserve pit.

e) A 48-inch high fence will be erected around the drillsite to discourage wildlife and domestic animals from entering. The fence will be of barbed wire and will have a toprail. To provide for crew safety, gates, stiles or other escape routes must be provided. A more substantial fence (chain link) may be required if grizzly bear conflicts occur. This fence will include a 16-foot cattleguard at the drillsite entry way. The fence will be maintained until rehabilitation efforts, including revegetation, have been completed. In the event of production, the fence, or a less extensive fence, will be used to enclose all production facilities at the wellsite.

f) The reserve pit shall be located and constructed so that surface water flow will not enter it with the exception of flow from on the drillsite itself.

g) The reserve pit shall be lined with an impervious, weather-resistant liner material to prevent contamination of surface or ground water. The installed liner shall be inspected by the BLM prior to filling with fluids.

Maintenance

Road maintenance needs and requirements were developed based on traffic volumes and characteristics for similar projects in an all weather/season situation. Specific information dealing with road maintenance standards can be found in the Project Transportation Analysis (Schaeffer 1984).

a) The operator shall provide maintenance made necessary by his use of the road constructed under this permit: <u>Provided</u>, the haulers of products from Federal lands and all other commercial haulers will be required to perform or bear their proportionate share of maintenance made necessary by their use of the road as determined by the Forest Service.

b) Uniform specifications for road maintenance contained in the Forest Service Transportation System Maintenance Handbook (FSH 7709.15) will be used.

c) The road surface and shoulders will be kept in a safe and usable condition, and will be maintained to original constructed standards.

d) Roads having in excess of 10 to 15 vehicles per day will be considered for dust control measures for safety and resource protection reasons. Approved dust palliatives will be applied as directed by the District Ranger. Dust control will normally be required from May 1 through October 31. The road surfaces to be treated shall be bladegraded, watered, shaped, and compacted before application.

e) All drainage ditches will be kept clear and free-flowing and will be maintained in accordance with original construction standards.

f) All culverts will be kept free of trash, free-flowing, and serviceable.

g) Damage to structures shall be repaired by temporary measures immediately and a plan for permanent repairs submitted to the district ranger within 10 days for approval.

h) The permittee shall keep the right-of-way free of trash.

i) Snowplowing:

1) Roads will be plowed out to the total width including ditch lines.
2) During snowplowing operation, the bank or road grade shall not be undercut, nor shall gravel or other select surfacing material be bladed off the roadway surface.
3) Ditches and culverts shall be kept functional during and following roadway use.
4) Dozers will not be used to plow snow on roads unless approved in advance by the District Ranger.

Road Reclamation

Road reclamation will consist of obliteration and revegetation. Obliteration activities include the removal of drainage structures (culverts) and associated fill material to the extent necessary to pass expected flood flow. Erosion control measures such as water bars and revegetation are required. Specific information relating to road reclamation can be found in the Project Transportation Analysis (Schaeffer 1984).

a) Reclaimed segments of the project road will be seeded with a grass mixture the first fall or spring after discing (whichever season comes first). The seed mixture will consist of:

Slender wheatgrass	@ 1.5 lb./ac.
Mountain brome	@ 3 lb./ac.
Bluebunch wheatgrass	@ 5 lb./ac.
Rough fescue (or if not available, then Idaho fescue)	@ 5 lb./ac.

b) The road surfacing material will be disced or ripped to break up compaction prior to seeding.

c) Revegetation of other roads obliterated will be done as directed by the Forest Service. Grizzly bear forage species will be used to revegetate obliterated roads where practical and will be consistent with natural plant composition to avoid attracting bears to travelways.

Pad Reclamation

Pad reclamation will consist of recontouring, spreading stockpiled topsoil and revegetation. Specific information can be found in the "Proposed Oil and Gas Development Guidelines," (Hadley 1983).

a) If this site is constructed and not drilled, the site and access road must be reclaimed within 90 days after expiration of the Drilling Permit, unless otherwise approved in writing by the area manager with the concurrence of the district ranger.

b) The operator will reshape the pad to former contours if the well turns out to be dry. After the pad is put back to its former contours, stockpiled topsoil will be evenly spread over the site and the site reseeded as prescribed in Road Reclamation, measure (a).

c) The reserve pit will be cleaned up and reclaimed within ninety (90) days after completion - or as soon as possible after it is not needed.

d) The fluids in the reserve pit will be allowed to evaporate or if any toxic material is in the drilling fluids, they will be vacuumed out and disposed off at an approved location.

e) If the reserve pit is to be left open during the winter snowpack period, the operator is required to maintain fluids at an acceptable level within the pit.

TECHNICAL APPENDIX 3
WATER RESOURCES

WATER QUALITY LAW, POLICY, AND STANDARDS

The Montana Water Quality Act (WQA) grants DHES the statutory authority to protect the quality of state waters for present and future beneficial uses. The Water Quality Act states that the Board of Health and Environmental Sciences shall: (1) establish standards for state waters; (2) establish a classification system for state waters; (3) require maintenance of the existing quality of state waters through a nondegradation policy; and (4) adopt rules and a permit system to control the discharge of contaminants to state waters.

A nondegradation policy has been established by the Board of Health to protect the present and future beneficial uses of surface water and groundwater. The nondegradation policy states that water which has a quality better than the established standard must be maintained at that high quality.

The nondegradation policy, water classifications and standards, and the existing quality and volume of receiving waters are used to formulate discharge limits and monitoring requirements specified in discharge permits. Discharge limits are calculated for discharges to surface water to ensure that the receiving stream can assimilate the pollutant discharge and that degradation of surface water does not occur. Discharges to groundwater are allowed a mixing zone within the property boundary of the person or organization doing the discharging where degradation up to the groundwater quality standard or existing groundwater quality may be allowed. However, mixing zones are not granted automatically and nondegradation of groundwater at the property boundary must not be degraded.

New discharges to surface water also must satisfy a nondegradation policy. Existing discharges are limited to protect beneficial use, and limitations have been developed to make sure that the stream can assimilate the discharge and that no detrimental effects on beneficial uses occur.

The Water Quality Bureau has adopted federal water quality standards to protect surface waters. It uses federal public drinking water standards to judge the quality of groundwater and bases classification on existing uses. These standards are shown in Table 3-1.

Table 3-1. Drinking Water Standards for Public Water Supplies

Parameter	
Primary Standards*	Maximum Contaminant Levels for Inorganic Chemicals (mg/l)
Arsenic	0.05
Barium	1.
Cadmium	0.010
Chromium	0.05
Lead	0.0005
Mercury	0.002
Nitrate as N	10.00
Selenium	0.01
Silver	0.05
Fluoride	1.4 - 2.4
Endrine	0.0002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
2, 4-D	0.1
2,4,5-TP Silvex	0.01
Secondary Standards**	Recommended Maximum Contaminant Levels (mg/l)
Chloride	250
Copper	1.0
Corrosivity	Non-corrosive
Iron	0.3
Manganese	0.005
pH	6.5 - 8.5 Std. Units
Sulfate	250
Zinc	5.0
Total dissolved Solids	500

* Primary standards are established to protect human health and define maximum permissible concentrations for each listed parameter.
**Secondary standards are developed to provide acceptable aesthetic and taste characteristics in drinking water. Recommended concentration limits have been established for the listed parameters.
Source: Title 16, Chapter 20, Subchapter 2, Administrative Rules of Montana.

The Water Quality Bureau also has adopted EPA guidelines for water quality criteria which recommend pollutant concentration limits based on the purpose and use for the water. These values are presented in Table 3-2.

Table 3-2. Matrix of Water Use Criteria (in milligrams per liter).

Variables	Uses/Criteria					
	* 1	* 2	* 3	* 4	* 5	* 6
Dissolved oxygen	7.0	5.0				
Fecal colifores (no./100 el)				200	1000	
Nitrite as N	0.05	0.05	1.0			10.0
Nitrate as N			10.0			
Nitrite and nitrate as N			10.0			100
Total anmonia			0.5			
Un-ionized anmonia	0.03	0.03				
Total inorganic N	1.00	1.00				
Total phosphorus	0.10	0.10		0.10		
Total dissolved solids			500		1200	10000
Conductance (microchos/cm)					1800	
Turbidity (NTU)	10	50				
Total suspended sediment	30	90				
Chloride			250		700	
Sulfate			250			
Cyanide	0.022	0.022	0.2			
Sodium					160	
Sodium adsorption ratio					5.0	
Fluoride			2.4		15.0	2.0
Arsenic	0.44	0.44	0.05		0.10	0.20
Barium			1.00			
Boron					0.75	5.00
Chronium VI	0.021	0.021	0.05		1.00	
Iron	1.0	1.0	0.3		20.0	
Manganese			0.05		10.0	
Selenium	0.26	0.26	0.01		0.02	0.05
Mercury	0.004	0.004	0.002			0.010
Temperature (C)	19.4	26.4				
Temperature (F)	67.0	80.0				
Copper**	0.012	0.012	1.0		5.0	0.5
Lead**	0.004	0.004	0.05		10.0	0.10
Zinc**	0.037	0.037	5.0		10.0	25.0
Chronium III**	4.7	4.7	17.8			
Nickel**	1.8	1.8	0.015		2.0	
Silver**	0.004	0.004	0.05			
pH (minimum)	6.5	6.5	6.5	6.5	4.5	
pH (maximum)	8.5	9.0	8.5	8.5	9.0	

* Beneficial uses:

1 - cold water aquatic life
2 - warm water aquatic life
3 - public water supplies
4 - primary contact recreation
5 - irrigation
6 - livestock watering

** Specific criteria for the protection of aquatic life are based on water hardness. Criteria values given are based on a water hardness of 100 mg/l.

Surface Water Resources

Montana includes all or part of 16 river basins (DHES 1986). These basins contain an estimated 20,532 stream miles. Lakes, reservoirs, and ponds number around 4,000 and cover an estimated 756,450 acres. The major river basins are the Missouri, Yellowstone, Clark Fork, and Kootenai basins. The four major basins are outlined in Figure 3-1 and tributaries, drainage area, and average discharge for each of these four basins are further described in Table 3-3.

Table 3-3. The Major Tributaries, Drainage Area, and Average Discharge for the Major River Basins in Montana.

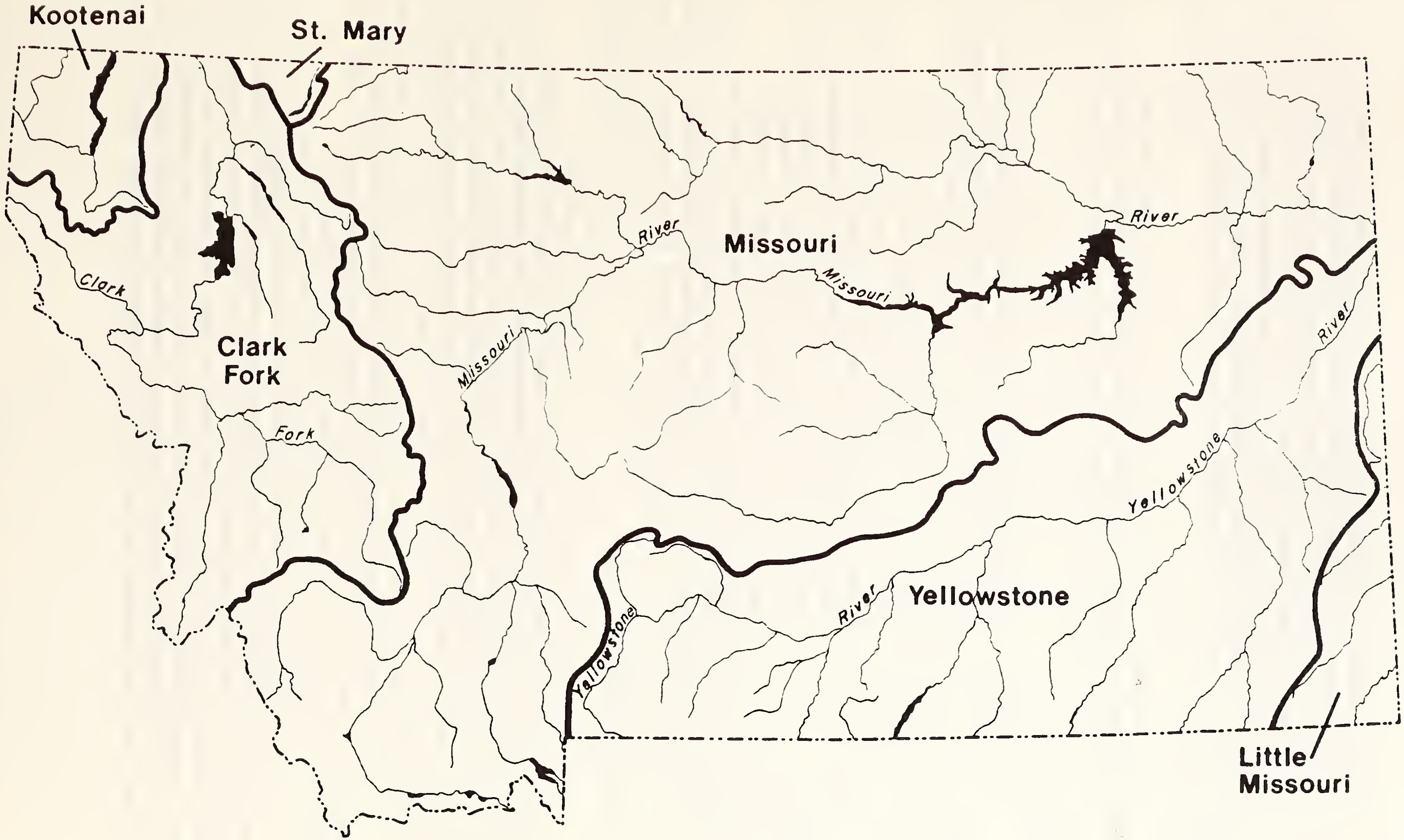
River Basin	Major Tributaries	Drainage Area ($mi.^2$)	Average Discharge (ft^3/s)
Missouri	Sun River Marias River Musselshell River Milk River	82,000	11,000 at Culbertson
Yellowstone	Clarks Fork Yellowstone River Bighorn River Tongue River Powder River	36,000	13,080 at Sidney
Clark Fork	Bitterroot River Flathead River	22,000	20,010 near Plains
Kootenai	-----	4,000	11,740 at Libby

Source: U.S. Geological Survey 1986.

Streams included in Class A are suitable for drinking water after simple disinfection. The quality of these streams is good because sediment in runoff is filtered out by forest soil as it drains to the streams and the water flows over relatively insoluble bedrock terrains. Class A streams normally contain no metals; have very low nutrient concentrations; are low in dissolved solids, turbidity and hardness; and meet primary and secondary drinking water standards.

Class B streams are lower quality than Class A but are considered suitable for drinking after conventional water treatment such as clarification, sedimentation, filtration, and sometimes lime softening. The major rivers in Montana are Class B streams, including the Missouri, Clark Fork and Yellowstone rivers. Class B streams contain low-to-nondetectable concentrations of metals, exhibit moderate levels of turbidity and total dissolved solids, and may occasionally contain nutrients and pesticides derived from agricultural areas or metals derived from mining wastes. The B classification is subdivided into subcategories which relate to fisheries supported by the streams.

MAJOR DRAINAGE BASINS OF MONTANA



Streams included in Class C generally do not meet secondary drinking water standards and are considered no better than marginally suitable for drinking. Class C streams are typically lowland streams that collect runoff from sparsely vegetated areas underlain by flat-lying, fine-grained sedimentary rocks. Class C waters usually contain concentrations of total dissolved solids and salts in excess of secondary standards. The C classification also is subdivided into subclasses based upon the fisheries the streams support.

The lowest stream classification is the Class I. Class I waters are only marginally useful for some limited agricultural or industrial purposes. Class I streams typically transport large amounts of sediment and waste.

Water Use

The most recent comprehensive assessment of water use in Montana was conducted by DNRC Water Resources Division. The Division's March 1986 report contains a compilation of data on Montana water use in 1980 (DNRC 1986b). The information was obtained from the National Water Use Data System which is a cooperative program between DNRC and the U.S. Geological Survey.

Most water used in Montana is surface water that is diverted for irrigation. Only a minimum of irrigation water is derived from groundwater resources. Water use information indicates that rural domestic water users rely almost entirely on groundwater as a source of potable water. Farms and ranches are scattered throughout the state and often are not near a readily available surface water supply; therefore, rural water users must rely heavily on groundwater. More than half of the water for industrial purposes is obtained from groundwater supplies. Two-thirds of municipal and livestock water demands are satisfied by surface water and one-third by groundwater.

AQUIFER CHARACTERISTICS

The Tertiary Fort Union Formation is a moderately consolidated sedimentary formation which functions as an aquifer in eastern Montana. The aquifer consists primarily of continental shale, siltstone, fine sandstone and coal. The Fort Union Formation has a known thickness of up to 2,200 feet and is exposed at the surface over vast areas of eastern and south-central Montana. Wells in the Fort Union Formation yield water for rural domestic and livestock needs.

Beneath the Fort Union Formation is a series of Cretaceous formations that consists mainly of alternating sandstone, shale, and siltstone layers. Sandstone units in this series transmit usable qualities of groundwater.

The lower part of the Hell Creek Formation consists of sandstone interbedded with siltstone and shale. Where present, the underlying Fox Hills Sandstone is connected hydraulically to the Hell Creek. Together, these two units compose the Hell Creek-lower Fox Hills aquifer. This aquifer is used most extensively in Carter, Custer, Prairie, and Fallon counties. Yields from the Hell Creek-lower Fox Hills generally are of a quality which can be used for stock and rural domestic purposes and for public supply in some areas.

Below the Fox Hills Sandstone is a series of aquifers that consists mainly of thick sandstone layers separated by confining shale layers. The sandstone aquifers commonly yield adequate supplies for most stock and rural domestic needs and, in places, may yield adequate water for public supplies. Most of the wells are drilled near the outcrop areas of the aquifers or where a satisfactory shallower source of supply is not available. The water-bearing sandstones described below are presented according to depth, beginning with the shallowest.

The Judith River Formation is composed of sandstone, siltstone, shale, and lignite, and varies in thickness from a few feet to about 400 feet. The Judith River Formation is developed most extensively as a source of water in Phillips, Blaine, Hill, and Valley Counties. Beneath the Judith River Formation lies the Eagle Formation which is one of the more widely used aquifers in this group of water-bearing sandstone formations. The Eagle Formation consists of about 250 feet of interbedded sandstone and shales. Wells tap the Eagle Formation for water in Hill, Liberty, Chouteau, Glacier, and Fergus counties.

The Kootenai Formation consists of 400 to 500 feet of red shale and brown-to-grey sandstone. The basal sandstone is about 100 feet thick and forms an excellent aquifer. Wells are drilled into the Kootenai Formation near the flanks of mountain ranges in Cascade, Judith Basin, Fergus, and Petroleum counties.

The Mississippian Madison Group is the lowermost widespread aquifer in eastern and central Montana. It consists mainly of limestone and some dolomite and is 700 to 1,500 feet thick. Rocks of the Madison Group crop out mostly in mountain ranges but dip steeply away from the mountains and lie deeply buried in most of the eastern part if the state. The Madison Group has not been used extensively for water supplies because of the deep drilling that is required to reach the aquifer. Quality of water may vary widely, depending on the depth of burial.

Groundwater in western and south-central Montana consists of alluvial, glacial, and basin-fill deposits of unconsolidated to semi-consolidated gravel, sand, silt, and clay. Adequate water supplies for domestic and stock purposes can usually be obtained from depths of less than 200 feet. Yields are often sufficient to supply irrigation, public supply, or industrial uses. Groundwater also can be obtained from consolidated bedrock formations located in mountainous terrains. The yield from wells constructed in mountain bedrock greatly depends upon the number of water-bearing fractures penetrated by the well bore.

In eastern and north-central Montana, groundwater is available from alluvial and glacial deposits. Alluvial deposits are present along major river valleys. Alluvial aquifers yield water to private and public supply wells installed in the valleys along rivers. Pleistocene glacial debris, deposited by continental ice sheets, forms a veneer over much of north-central and northeastern Montana. Glacial aquifers hold adequate water supplies for stock and domestic needs. Ancient stream gravels buried by glacial drift are sometimes very productive, yielding sufficient water for irrigation.

AMOUNTS AND TYPES OF OIL AND GAS WASTES

Two estimates of the total volume of drilling fluids produced by drilling operations in each oil-producing state have been formulated by EPA (1987a) and the American Petroleum Institute (API 1987a). The EPA estimates are based on equating the volume of drilling fluid generated with the size of the reserve pit constructed to service a well. API estimates are based on a questionnaire sent to a sample of operators, asking for estimated volumes data for drilling and completion fluids, drill cuttings, and other associated wastes discharged to the reserve pit.

EPA estimated that for 591 wells drilled in Montana in 1985, 36,302,000 barrels (bbls) of drilling fluid were produced, or 61,425 bbls per well. API estimated that for 623 wells drilled in Montana in 1985, 4,569,000 bbls were produced, or 7,334 bbls per well. EPA reviewed API's survey methodology and believes the API method is more reliable in predicting actual volumes generated. The lower estimate of 7,334 bbls translates into slightly over 308,000 gallons of waste drilling fluid for each well.

Davis (1987) conducted a survey to determine the types and amounts of drilling fluids used nationwide. Davis sent a questionnaire to drilling fluid engineers and drilling fluid suppliers familiar with drilling practices in 22 of the major onshore oil and gas producing basins. The Williston and Powder River basins, which extend into Montana, were included in Davis' survey. Davis also reviewed the EPA study and other studies in which reserve pit wastes were sampled and analyzed to assess the nature of drilling fluid wastes.

Davis reviewed and compiled results from analysis of drilling fluid, reserve pit bottoms, and sludge from storage tanks (see tables 3-4, 3-5, and 3-6). Weighted mean concentrations of chloride, total suspended solids, and total dissolved solids measured in liquid samples of reserve pit wastes exceeded drinking water standards. Nitrate/nitrite pH concentrations and pH in samples of solids exceeded drinking water standards. Weighted mean concentrations of barium, cadmium, chromium, fluoride, iron, lead, manganese and zinc measured in both liquid and solid samples from reserve pits exceeded drinking water standards. At these levels, drilling muds and fluids cannot be discharged to surface waters and could not be disposed, so the potential for groundwater contamination exists.

A variety of organic compounds were detected in solid and liquid samples of reserve pit wastes. Drinking water standards have not been established for many of the organic compounds. Weighted mean concentrations of benzene, ethylbenzene, pentachlorophenol, and toluene measured in solid samples exceeded both existing and proposed drinking water standards. Although the results from the Davis analysis of reserve pit wastes are not entirely representative of wastes in Montana, the results can be used as a guide to constituents of concern.

Murphy and Kehew (1984) sampled and analyzed drilling fluid from an oil well drilling site in western North Dakota. The drilling site was located in the Williston Basin oil field which extends into eastern Montana. The results of analysis of the fluid are presented in Table 3-7. Results of analysis show that drilling fluid contains an extremely high concentration of total

Table 3-4. Conventional Pollutants Measured in Samples Collected from Reserve Pits (Davis 1987)

Conventional Analytes

ANALYTE Phase	N	Ndet	Min. mg/l	Wtd. Mean mg/l	Max. mg/l	EPA Drinking Water Std. MCL, mg/l	RMCL, mg/l
pH							
Liquid	17	17	6.5	7.7	12.7		6.5-8.5
Solid	20	20	6.8	9.0	12.8		Std.Units
CHLORIDE							
Liquid	17	17	200	6,700	47,000		250
Solid	20	20	570	39,000	140,000		
NITRATE/NITRITE							
Liquid	17	14	<D.L.	5.7	85	10.0	
Solid	20	14	<D.L.	77	610		
TOTAL SUSPENDED SOLIDS							
Liquid	16	16	220	18,000	110,000	1 Turbidity Unit	
TOTAL DISSOLVED SOLIDS							
Liquid	16	15	<D.L.	38,000	180,000		500
OIL & GREASE							
Liquid	17	17	3.0	480	1,800		
Solid	20	20	800	33,000	280,000		

N = Number of samples
Ndet = Number of samples in which the parameter was detected
Min. = Minimum value measured
Wtd. Mean = Weighted mean measured values
Max. = Maximum value measured
mg/l = Milligrams per liter
<D.L. = Less than detection limit
MCL = Maximum contaminant level
RMCL = Recommended maximum contaminant level

Table 3-5. Total Metals Concentrations Measured in Samples Collected from Reserve Pits (modified after Davis 1987).

				Total Metals			
ANALYTE Phase	N	Ndet	Min. mg/l	Wtd. Mean mg/l	Max. mg/l	EPA Drinking Water Std. MCL, mg/l	RMCL, mg/l
ALUMINUM							
Liquid	17	16	<D.L.	200	3,800		
Solid	21	21	2,300	9,600	21,000		
ARSENIC							
Liquid	17	6	<D.L.	0.044	0.22	.05	
Solid	21	11	<D.L.	4.1	29		
BARIUM							
Liquid	17	17	0.19	42	18,700	1.0	
Solid	21	21	30	8,900	56,000		
BERYLLIUM							
Liquid	17	9	<D.L.	0.0097	0.036		
Solid	21	3	<D.L.	0.0	3.0		
BORON							
Liquid	17	16	<D.L.	17	50		
Solid	21	18	<D.L.	75	290		
CADMIUM							
Liquid	17	13	<D.L.	0.058	2.2	.01	
Solid	21	13	<D.L.	4.0	14		
CALCIUM							
Liquid	17	17	170	1,100	24,000		
Solid	21	21	9,400	40,000	140,000		
CHROMIUM							
Liquid	17	14	<D.L.	1.4	330	.05	
Solid	21	20	<D.L.	34	370		
COBALT							
Liquid	17	9	<D.L.	0.12	0.5		
Solid	21	5	<D.L.	0.1	17		
COPPER							
Liquid	17	13	<D.L.	0.36	36		1.0
Solid	21	18	<D.L.	35	82		
FLUORIDE							
Liquid	17	17	0.8	10	310	1.4-2.4	
Solid	20	20	5.4	480	1,800		

Table 3-5. (cont.)

Total Metals

ANALYTE Phase	N	Ndet	Min. mg/l	Wtd. Mean mg/l	Max. mg/l	EPA Drinking Water Std. MCL, mg/l	RMCL, mg/l
IRON							
Liquid	17	16	<D.L.	370	6,300		0.3
Solid	21	21	3,100	24,000	57,000		
LEAD							
Liquid	17	12	<D.L.	0.69	52	.05	
Solid	21	12	<D.L.	80	450		
MAGNESIUM							
Liquid	17	17	0.69	180	3,400		
Solid	21	21	1,400	6,500	16,000		
MANGANESE							
Liquid	17	17	0.11	5.2	120		.05
Solid	21	21	120	450	940		
MERCURY							
Liquid	17	3	<D.L.	0.0004	0.006	.002	
Solid	21	3	<D.L.	0.0	2.1		
MOLYBDENUM							
Liquid	17	13	<D.L.	0.12	0.58		
Solid	21	2	<D.L.	0.6	16		
NICKEL							
Liquid	17	15	<D.L.	0.31	6.1		
Solid	21	15	<D.L.	25	61		
POTASSIUM							
Liquid	17	15	<D.L.	2,300	4,000		
Solid	21	10	<D.L.	3,000	170,000		
SILICON							
Liquid	17	16	<D.L.	69	1,000		
Solid	21	15	<D.L.	1,700	15,000		
SILVER							
Liquid	17	7	<D.L.	0.0004	0.019	.05	
Solid	21	6	<D.L.	0.0	9.1		
SODIUM							
Liquid	17	17	190	13,000	59,000		
Solid	21	21	580	27,000	67,000		

Table 3-5. (cont.)

Total Metals

ANALYTE Phase	N	Ndet	Min. mg/l	Wtd. Mean mg/l	Max. mg/l	EPA Drinking Water Std. MCL, mg/l	RMCL, mg/l
STRONTIUM							
Liquid	17	17	1.1	24	590		
Solid	21	8	<D.L.	160	1,100		
SULFUR							
Liquid	17	15	<D.L.	230	5,900		
Solid	21	21	1,200	7,000	20,000		
TIN							
Liquid	17	12	<D.L.	0.3	2.3		
Solid	21	8	<D.L.	13	100		
TITANIUM							
Liquid	17	12	<D.L.	0.55	32		
Solid	21	21	17	140	550		
VANADIUM							
Liquid	17	11	<D.L.	0.28	1.7		
Solid	21	15	<D.L.	12	74		
YTTRIUM							
Liquid	17	10	<D.L.	0.12	18		
Solid	21	2	<D.L.	0.1	12		
ZINC							
Liquid	17	17	0.03	1.5	100		5.0
Solid	21	21	22	140	820		

N = Number of samples
Ndet = Number of samples in which the parameter was detected
Min. = Minimum value measured
Wtd. Mean = Weighted mean measured values
Max. = Maximum value measured
mg/l = Milligrams per liter
<D.L. = Less than detection limit
MCL = Maximum contaminant level
RMCL = Recommended maximum contaminant level

Table 3-6. Organic Compounds Measured in Samples Collected from Reserve Pits (modified after Davis 1987).

ANALYTE Phase	N	Ndet	Min. mg/l	Wtd. Mean mg/l	Max. mg/l	EPA Drinking Water Std. MCL, mg/l	PMCL, mg/l
BENZOIC ACID							
Liquid	15	3	<D.L.	0.012	0.19		
Solid	19	1	<D.L.	0.0001	0.03		
BENZENE							
Liquid	16	1	<D.L.	0.0009	0.017	.005	
Solid	18	7	<D.L.	0.096	1.4		
ETHYLBENZENE							
Liquid	16	2	<D.L.	0.0001	0.23		.68
Solid	18	7	<D.L.	1.5	12		
2-BUTANONE							
Liquid	16	6	<D.L.	0.0072	1.6		
Solid	18	6	<D.L.	14	45		
CARBON DISULFIDE							
Liquid	16	2	<D.L.	0.0001	0.022		
Solid	18	2	<D.L.	0.012	0.021		
p-CYMENE							
Liquid	15	3	<D.L.	0.016	0.043		
Solid	19	3	<D.L.	14	131		
n-DECANE							
Liquid	15	6	<D.L.	0.76	21		
Solid	19	9	<D.L.	1.6	19		
n-EICOSANE							
Liquid	15	11	<D.L.	4.1	90		
Solid	19	14	<D.L.	150	1,400		
n-HEXADECANE							
Liquid	15	10	<D.L.	4.7	170		
Solid	19	16	<D.L.	590	5,500		
HEXANOIC ACID							
Liquid	15	2	<D.L.	0.0088	0.075		
NAPHTHALENE							
Liquid	15	5	<D.L.	0.044	1.4		
Solid	19	7	<D.L.	47	450		
2-METHYLNAPHTHALENE							
Liquid	15	6	<D.L.	0.081	8.7		
Solid	19	9	<D.L.	0.012	0.11		

Table 3-6. (cont.)

ANALYTE Phase	N	Ndet	Min. mg/l	Wtd. Mean mg/l	Max. mg/l	EPA Drinking Water Std. MCL, mg/l	PMCL, mg/l
4-METHYL-2-PENTANONE							
Liquid	15	6	<D.L.	0.026	2.0		
Solid	19	4	<D.L.	0.0009	0.032		
PHENANTHRENE							
Liquid	15	3	<D.L.	0.21	6.0		
Solid	19	1	<D.L.	0.014	2.6		
PHENOL							
Liquid	15	3	<D.L.	0.0038	0.32		
Solid	19	1	<D.L.	0.045	8.3		
PENTACHLOROPHENOL							
Liquid	15	1	<D.L.	3.8	60		.220
Solid	19	1	<D.L.	5.1	270		
bis(2-ETHYLHEXYL) PHTHALATE							
Liquid	15	5	<D.L.	0.0021	1.4		
Solid	19	9	<D.L.	3.4	8.5		
2,3,7,8-TCDD (Dioxin)							
Solid	4	2	<D.L.	9.2 ng/kg	13.6 ng/kg		
TOLUENE							
Liquid	16	6	<D.L.	0.19	0.44		2.0
Solid	18	9	<D.L.	1.2	6.3		

N = Number of samples
Ndet = Number of samples in which the parameter was detected
Min. = Minimum value measured
Wtd. Mean = Weighted mean measured values
Max. = Maximum value measured
mg/l = Milligrams per liter
<D.L. = Less than detection limit
MCL = Maximum contaminant level
PMCL = Proposed maximum contaminant level

Table 3-7. Results of Analysis of a Sample of Drilling Fluid Collected from a Reserve Pit at a north Dakota Drill Site (modified after Murphy and Kehew 1984).

Parameter		Concentration
Specific Conductance	Cond. mhos/cm.	203,000
Total Dissolved Solids	(TDS) mg/L	257,000
Iron	(Fe) mg/L	4.5
Manganese	(Mn) mg/L	0.92
Calcium	(Ca) mg/L	8250
Magnesium	(Mg) mg/L	166
Potassium	(K) mg/L	1510
Sodium	(Na) mg/L	70,500
Chloride	(Cl) mg/L	175,000
Sulfate	(SO_4) mg/L	887
Bicarbonate	(HCO_3) mg/L	213
Fluoride	(F) mg/L	0
Percent Sodium	(% Na)	87.7
Arsenic	(As) mg/L	451
Barium	(Ba) ug/L	0
Cadmium	(Cd) ug/L	59.2
Chromium	(Cr) ug/L	331
Copper	(Cu) ug/L	650
Lead	(Pb) ug/L	346
pH	(pH)	7.2
Selenium	(Se) ug/L	0
Zinc	(Zn) ug/L	300
Nitrate (reported as N)	(No_3) mg/L	1030

dissolved solids, sodium, chloride, and nitrate. Arsenic, cadmium, chromium, lead, sulfate, and zinc were also detected in the fluid at concentrations that exceed primary or secondary drinking water standards by several orders of magnitude. These results are probably typical of drilling fluid wastes at drilling sites located in the portions of eastern Montana in the Williston Basin.

EPA (1987a) sampled and analyzed wastes from production facilities. Samples of liquid and tank bottom sludge were collected from tanks, separation vessels and produced water storage/evaporation ponds. Benzene, phenanthrene, barium, fluoride, and antimony were detected in liquid wastes samples. Benzene, phenanthrene, and arsenic were detected in separator tank bottom sludge. These results can be used as a guide to constituents of concern that may be present in production facility wastes in Montana.

Beal et al. (1987) evaluated the migration of contaminants from buried oil and gas drilling wastes in north-central North Dakota. Beal studied the Williston Basin oil field. For the study, Beal compiled the results from the analysis of 69 samples of produced water collected from production wells in the area. Table 3-8 summarizes the results of the produced water analysis.

Table 3-8. Concentrations of Common Ions Measured in Produced Water Collected from a North Dakota Oil Field (values in mg/l).

Parameter	High	Low	Mean
Total dissolved solids	335,542	4,148	233,439
Calcium	31,360	539	6,436
Magnesium	4,720	168	1,469
Sodium	121,674	4,584	82,012
Chloride	204,260	899	141,354
Sulfate	4,000	112	1,601

SOURCE: Beal et al. 1987

The results of the analyses show that the mean concentration of total dissolved solids measured in the produced water samples was very high and the water would be considered a brine. Mean concentrations of chloride and sodium were extremely high and significant levels of calcium, magnesium and sulfate were also detected. The produced water samples are probably representative of produced water that would be generated at production operations located in the eastern portion of Montana located in the Williston Basin.

POWDER RIVER PROBLEM

A controversial interstate surface water quality and quantity problem, associated with the discharge of produced waters from a Wyoming oil field, was brought to the attention of the Water Quality Bureau in 1983. The Wyoming Water Development Commission prepared a draft report on a proposed water storage development plan for the Powder River Basin. Good quality spring runoff water was to be captured by small dams and held for irrigation in the summer. Wyoming's Water Quality Agency also had issued several surface water discharge permits to oil producers located in Wyoming's Salt Creek oil field.

Discharges of produced water were allowed under limits placed on them through permits so that downstream ranchers could beneficially use the produced water for stock and wildlife purposes. Runoff from the Salt Creek oil field, laden with salts from produced water discharges, drains directly into the Powder River just outside the Montana and Wyoming border.

The Cooperative Extension Service at Montana State University is conducting a study of the relationship between irrigation water from the Powder River, soil salinity, crop production, and possible decreased water quality as a result of discharges from the Salt Creek oil field to the Powder River before the stream enters Montana from Wyoming. The study was promoted by concern over a water storage project in Wyoming which could reduce diluting flows in the Powder River, causing increased TDS concentrations in water used downstream to irrigate alpha in Montana. Not much progress has been made towards resolution of this controversy. However, impacts to the quality of Powder River water have not yet been documented.

The concern voiced by various Montana agency officials and by Montana irrigators was that the reduced flow of the Powder River would not adequately dilute the runoff from the Salt Creek oil field, and, as a result, downstream uses of the river water would be adversely impacted.

The existing quality of the Powder River water is considered marginal at best for irrigation of alfalfa in Montana. The USGS staff (Pike 1984) reviewed historical water quality data for the Powder River in Wyoming and Montana, collected between 1974 and 1978, and concluded that under present conditions TDS concentration did not increase appreciably as the water flows out of Wyoming into Montana. An analysis conducted by the Water Resources Division of the Montana DNRC (1983) concluded that if the development plan was implemented, the long-term average concentration of TDS concentration in the Powder River would increase from 1,054 mg/l to 1,273 mg/l.

RECORD OF COMPLAINTS

The following sections describe in greater detail the material summaries in the water quality section of the draft programmatic impact statement.

Dewey Study

This section contains information collected by a contractor working for DHES. The report submitted to the Water Quality Bureau focused on susceptible hydrogeologic locations where improper drilling site construction or reclamation were noted in Richland County, part of the Williston Basin oil-producing region (Dewey 1982).

Site 1: SW NE Sec. 36, T. 24 N., R. 48 E., Richland County

Description: An oil well was drilled at this site in the spring in 1981. A citizen complained to the Oil and Gas Division on May 21, 1982 that wastes from the drilling operation were contaminating First Hay Creek, located near the site. The Oil and Gas Division inspectors investigated the site on May 22, 1981 and discovered that one edge of the reserve pit was only 50 feet from First Hay Creek. Water from the creek had a salty taste. It was assumed that since there was no visible evidence of overland flow of drilling fluids from

the drill site, that wastes from the reserve pit were leaking from the pit and migrating to the creek via groundwater flow.

The hole was completed and no measures were implemented to stop the seepage of wastes. Water samples collected from the creek by the Water Quality Bureau on June 3, 1981 showed chloride increased from 11.6 mg/l above the pit to 1,399 mg/l immediately below the pit. The drilling company collected samples from the creek for the next 11 months to monitor the level of water pollution. Results of this monitoring are presented in Table 3-9.

Table 3-9. Results of Chloride Analysis for Samples Collected from First Hay (in mg/l).

Date	200' above Pit	200' below Pit	3 Miles Downstream
3 June 81	11.6	1399	109
9 June 81	32	2624	144
16 June 81	29	2424	140
23 June 81	18	1869	126
30 June 81	16	1944	112
7 July 81	24	2120	112
14 July 81	40	2264	144
21 July 81	40	2112	120
19 Aug 81	32	1760	112
1 Sept 81	40	1736	98
16 Sept 81	24	1632	109
30 Sept 81	28	1352	111
14 Oct 81	33	1382	95
31 Oct 81	25	1284	111
18 Nov 81	47	1186	112
9 Dec 81	29	1153	90
14 Apr 82	13.6	30.6	99.5

Results of the company's monitoring show that during summer 1981 the concentration of chloride in the creek immediately below the pit was approximately 50 to 127 times higher than the chloride content of the creek above the pit. During the later portion of the year the chloride content of the creek water below the pit ranged from 25 to 50 times higher. Monitoring of the creek water 3 miles downstream from the pit showed an increase in chloride ranging from 3 to 9 times higher than background.

The drilling company failed to recognize and correct the problem. Impacts to existing water users and aquatic life are unknown.

Site 2: SE NE Sec. 17, T. 30 N., R. 58 E., Richland County

Description: An oil well was drilled at this location in early 1980. In March 1980, while the well was still being drilled, the landowner noticed that the reserve pit liner was torn and reported it to the Oil and Gas Commission. The agency condemned the pit but the drilling company did not implement any repairs.

Five 12-foot deep holes were dug downslope from the pit by the landowner and Oil and Gas Division field staff at distances ranging from 25 to 360 feet. Soil samples collected from the holes were analyzed for chloride content. All of the samples, except those from the hole 25 feet from the pit, had chloride concentrations that ranged from 0.01 to 0.05 meq/100g. A sample of soil from the bottom of the hole nearest the pit had a chloride content of 29.0 meq/100g which is 580 times higher than other samples at 0.05 meq/100g.

Results of soil analysis indicated that drilling fluids leaked from the pit into the subsurface and increased the chloride content of soils in the vicinity. Changes in the quality of water in a creek situated 3/4 mile below the drill site were not detected. Future impacts to underlying groundwater and existing water users is unknown.

<u>Site 3</u>: SE NE Sec. 15, T. 23 N., R. 59 E., Richland County

Description: A landowner learned that an oil well would be drilled adjacent to his property, 300 feet from his water well. As a precaution, the landowner collected a sample of water from his 19-foot deep water well in September 1979. The oil well was completed in January 1980. Drilling fluids from the reserve pit were drained by the trenching method and muds were buried on site.

In mid-February 1980, the landowner noticed that his well water began to taste salty and again had a water sample analyzed. Comparison of the September 1979 and the February 1980 samples showed a significant increase in dissolved ion content of the water: sodium, from 64.9 to 813 mg/l; magnesium, from 43.6 to 178 mg/l; and chloride, from 12.2 to 1,940 mg/l. Total dissolved solids increased from 782.2 to 3,865.9 mg/l and specific conductance increased from 933 to 6,630 uhmos/cm.

The landowner rejected an offer of $5,000 from the oil company for compensation for his ruined water supply. In April 1980 the oil company paid to have a new water well drilled for the landowner.

<u>Site 4</u>: SW SE Sec. 36, T. 24 N., R. 59 E., Richland County

Description: An oil well was drilled at this site in early 1979. The landowner was concerned about potential surface or groundwater pollution from what he viewed as an inadequately lined reserve pit. Water samples were collected from an irrigation return ditch located adjacent to the drilling site. Results from the analysis of ditch water are presented on Table 3-10.

Table 3-10. Chloride in Water Samples Collected from Irrigation Return Ditch Located Adjacent to Site 4.

Date	Ditch Water 600 ft. Above Drill Site	Ditch Water Adjacent to Drill Site
1/16/79	10.8	30.2
2/29/79	10.8	364.0
5/07/80	11.2	25.8
4/16/82	33.5	57.8

The first samples collected on January 16, 1979 showed the concentration of chloride in the ditch water was 10.8 mg/l above the drilling site and 30.2 mg/l below the site. Samples collected on February 26, 1979 revealed 10.8 mg/l of chloride in ditch water above the site and 364.0 below. Samples collected in May 1980 and April 1982 showed a decrease in chloride content to levels measured in January 1979.

Site 5: NE SW Sec. 32, T. 27 N., R. 54 E., Richland County

Description: The reserve pit constructed at this drilling site was placed in a gravel bed 200 feet from a creek. Analysis of reserve pit liquid showed drilling fluid to contain large amounts of salts. Analysis of creek water above and below the drilling site did not show any significant change in water quality based on an analysis of conductivity which is used to indicate increased levels of salt.

No immediate impacts to water quality were detected. Dewey believed the potential for surface and groundwater degradation was great because drilling fluid, either during drilling or after reclamation, could migrate through permeable gravel materials into underlying groundwater and nearby surface water. Additional monitoring was not conducted to determine extent or magnitude of the potential problem.

Site 6: NE NW Sec. 3, T. 23 N., R. 59 E., Richland County

Description: The reserve pit liner at this location was torn. The pit was reclaimed using the "squeezing" method where dirt is pushed into the pit to concentrate pit liquids into one portion of the pit. Squeezing activities destroy the integrity of pit liners because heavy equipment is used to move dirt from pit berms into the pit. This method of reclamation allows pit liquids to soak into surrounding soil. Impacts to water resources are unknown.

Site 7: SE NW Sec. 23, T. 23 N., R. 55 E, Richland County

Description: The reserve pit liner at this location was torn. The pit also was constructed across a small intermittent drainage and blocked the flow of runoff water. Sediment, eroded off the sides of the pit berm, contributed sediment to nearby surface water.

Site 8: NE NW Sec. 17, T. 24 N., R. 59 E., Richland County

Description: The reserve pit liner at this site was torn. The site was not reclaimed for over 18 months because of financial difficulties. Analysis of pit liquid showed a specific conductivity of 49,200 umhos/cm which indicates the high dissolved solids content of the liquid.

Site 9: NW SW Sec. 33, T. 27 N., R. 59 E., Richland County

Description: An oil well was drilled at the above location and the reserve pit was not lined. The landowner was concerned that his stock well 1/4 mile away would be polluted. A small spring also was located in the drainage immediately downslope from the reserve pit. Samples of water from the well and the spring were collected and analyzed. The results of analysis did not indicate that the quality of water had been affected at the time of sampling. It was recommended to the landowner that the water be retested in the future.

Site 10: NE Sec. 27, T. 35 N., R. 57 E., Sheridan County

Description: The reserve pit at this drilling location was left overflowing after drilling operations had ceased. The landowner was concerned about drilling fluids flowing on to this land. The oil company representatives said the liquid was fresh water and asked the landowner if they could dispose of it on his land. Analysis of a sample of pit liquid showed a specific conductivity of 5,100 umhos/cm indicating that the liquid was brackish. The landowner refused to allow the oil company to dispose of the liquid on his land. The eventual fate of the site is unknown.

Complaints Filed with the Water Quality Bureau

The information contained here was summarized from data contained in DHES files. The detail of information on resolution of complaints varies due to the way that complaints were handled. Coordinated record keeping of the complaints does not exist so it is difficult to determine what action, if any, was taken following the filing of a complaint. This is especially true where complaints were referred to oil agencies for resolution.

Complaint #1:

Date: January 7, 1987
Location: SW Sec. 21, T. 35 N. R. 3 E., Toole County

Description: A gas well was drilled at this location in early 1987. Wells that supply water for the town of Galata are located near the drilling site. The Galata Water District learned that circulation was lost while drilling the gas well and several drilling additives were used to regain circulation. The District was concerned that drilling fluid additives could escape from the well and contaminate the city supply. The District contacted the Oil and Gas Division and the Water Quality Bureau to inquire about drilling fluid additives and possible impacts to groundwater.

The drilling company responded to a request for information from the Water Quality Bureau and provided details on the circulation problem and drilling additives. Circulation was lost at 75 feet and 32 sacks of gel and 2 sacks of

lime were added to the mud to seal the hole. A variety of other additives; including 15 sacks of cottonseed hulls, 15 sacks of cedar fiber, 6 sacks of caustic lignite, 6 sacks of sawdust, and 2 sacks of caustic soda, were added to drilling mud before the well was completed.

The Galata city wells are approximately 285 feet deep. Materials used during drilling could conceivably enter the aquifer and contaminate the groundwater and affect the city's water supply. There is no indication that the water supply has been contaminated.

Complaint #2:

Date: March 24, 1987
Location: Sec. 35, T. 31 N., R. 42 E., Valley County

Description: A citizen contacted the Oil and Gas Division to complain about a drilling fluid disposal pit that had a torn liner. The pit was operated by a service company on private land for the disposal of drilling fluids from oil and gas drilling operations located throughout the area. The citizen was concerned that the liner was torn and that drilling fluids might leak from the pit and contaminate his nearby stock well. The Oil and Gas Division referred the problem to the Water Quality Bureau indicating that they did not have jurisdiction because the pit was not associated with an active drilling site. The service company did not pursue either a Montana Groundwater Pollution Control System (MGWPCS) permit or a solid waste disposal license.

The Water Quality Bureau contacted the local county sanitarian who traveled to the site to examine the pit and collect water samples. The inspection revealed that the liner was indeed torn and wastes had leaked into the subsurface. Samples of pit fluid and water from the citizens stock well were collected. The samples showed that the pit liquid had 6,370 mg/l of chloride, 1,545 mg/l sulfate and <.01 mg/l nitrate. Analysis of the stock well water showed 346 mg/l chloride, 2,283 mg/l sulfate and 13.4 mg/l nitrate.

It was noted that the well was upgrade from the disposal pit and that wastes were not likely to migrate to the well.

The elevated nitrate concentration in the stock well indicated that the well may be affected by other sources of pollution, including agricultural chemicals. The Water Quality Bureau wrote a letter to the citizen explaining the results and the matter was referred to the Oil and Gas Division for condemnation and reclamation.

Complaint #3:

Date: March 31, 1987
Location: Sec. 10, T. 7 N., R. 60 E., Fallon County

Description: A citizen contacted the Oil and Gas Division to express concern about oil well workover operations conducted by Challenger Minerals Inc. (CMI) on his property. The citizen was concerned about possible degradation of surface and groundwater quality caused by oil spilled during a pipeline break, dripping chemical pumps, overflows from drip pans under truck loading lines, and overflows from the well head cellars.

The Oil and Gas Division referred the complaint to the Water Quality Bureau for investigation. The Water Quality Bureau staff inspected the site and determined that the releases of materials occurred over the Fox Hills-Hell Creek aquifer, posing a threat to groundwater. The Water Quality Bureau asked the company to clean up spilled materials and to install corrective measures to prevent future releases. The company excavated and removed a portion of the soil contaminated with oil and implemented some corrective measures. The landowner is still concerned about the adequacy of the cleanup.

Complaint #4:

Date: July 15, 1986
Location: Sec. 9, T. 9 N., R. 59 E., Fallon County

Description: The Fallon County Sanitarian contacted the Water Quality Bureau to report that water from an abandoned oil well was being discharged to state waters. The reserve pit at the drill site has been condemned by the Oil and Gas Division on July 2, 1984 because it was improperly constructed. In addition, the landowner converted the abandoned well to a stock water supply well. Water was pumped from the well into a stock tank where it overflowed into a nearby drainage. The water from the well had a measured chloride content of 1,700 mg/l.

The discharge of the water was conducted without a permit and as such was considered a violation of the Water Quality Act. An agreement was reached with the landowner to pump only enough water from the well to fill the stock tank, so water would not overflow.

Complaint #5:

Date: June 12, 1986
Location: Sec. 12, T. 22 N., R. 58 E., Richland County

Description: The Water Quality Bureau learned of an illegal disposal pit being operated at the above location. A landowner constructed the pit on his own property without a permit for use as a commercial drilling fluid disposal site. Nearby residents expressed concern that wastes leaking from the pit might contaminate their well water. The landowner was contacted and he said he lined the pit but denied that any drilling fluids were accepted for disposal. The operator said he only disposed of demolition debris and animal wastes in the pit. A nearby homeowner reported that he followed a truck from a drilling site to the pit where drilling wastes were dumped into the pit.

Water Quality Bureau and Richland County personnel investigated the site in September 1987. The pit had been filled and the was covered with soil at the time of the site visit. Although the pit was apparently lined, the method of construction and integrity of the liner is unknown. A thin plastic liner was evident at the surface. Two domestic supply wells were located less than 500 yards from the pit. Test pits were excavated with a backhoe and materials in and around the pit were sampled. Results of the field investigation and sample analysis revealed that drill cuttings and hydrocarbons were present in the pit. The landowner has left the state and the Water Quality Bureau investigation will continue.

Complaint #6:

Date: January 27, 1986
Location: Five miles east of Sidney MT, Richland County

Description: Montana Department of Fish, Wildlife and Parks Department (DFWP) staff complained to the Water Quality Bureau about an oil company drilling crew that was dumping waste crankcase oil in an abandoned reserve pit. Stock ponds were located downslope from the reserve pit and DFWP was concerned about possible contamination of water. The reserve pit and drilling site had been abandoned for approximately two months. The Water Quality Bureau staff asked the Oil and Gas Division to investigate the site, remove waste oil from the pit, and properly reclaim the pit.

Complaint #7:

Date: January 2, 1986
Location: Sec. 14, T. 37 N., R. 5 W., Glacier County

Description: The Water Quality Bureau received a citizen complaint about a discharge of marginal quality produced water from an evaporation pond. EPA staff investigated the site on January 5, 1986. The EPA inspector discovered that the berm around the pond had eroded and produced water was flowing out of the pond into a drainage that led about 75 feet to Red Creek. The representative of the oil company responsible for the pond claimed that the pond overflowed because of recent snowmelt.

The Water Quality Bureau sent a letter to the oil company requesting that the problem be corrected or that the company apply for an MPDES permit to beneficially reuse the water. The oil company lowered the liquid level in the pond, repaired the berm, and modified structures designed to control liquid levels.

Complaint #8:

Date: September 17, 1985
Location: Sec. 34, T. 28 N., R. 32 W., Sanders County

Description: Forest Service personnel reported to the Water Quality Bureau that a pit at an oil drilling site was overflowing into a tributary drainage of the Bull River. Surface water from the surrounding area was draining into the reserve pit and causing the pit to overflow. A spill of diesel fuel also occurred when a tanker truck delivered fuel to the site. Drilling fluid from the pit and diesel fuel entered the nearby stream. Quality of surface water was degraded for a time. Impacts to aquatic life and water users are unknown.

The USFS worked with the drilling company to correct problems at the site. Fuel-contaminated soil was removed, and a diversion ditch was constructed to divert surface water away from the reserve pit. After the well was completed, drilling fluid and cuttings were removed from the pit, the pit was refilled, and the site was revegetated.

Complaint #9:

Date: June 28, 1985
Location: Sec. 19, T. 35 N., R. 1 W., Toole County

Description: A citizen complained to the Water Quality Bureau that oil and water were flowing from an abandoned oil well near Sunburst. The citizen also was concerned that the oil company responsible for the well was selling the property and evading the responsibility. Oil and water from the well caused salt and oil seeps downgrade from the well. Impacts to water may occur but have not been documented. The final resolution of the problem is unknown.

Complaint #10:

February 22, 1985
Location: Sec. 7, T. 34 N., R. 1 W., Toole County

Description: A citizen reported to the Water Quality Bureau that an abandoned oil well was discharging approximately 5 gpm of water. The water ran over the surface and drained into a stock pond on his land. The Water Quality Bureau passed the complaint to the Oil and Gas Division. The quality of water from the well and impacts to the pond are unknown.

Complaint #11:

Date: February 19, 1985
Location: Sidney, Montana, Richland County

Description: A citizen complained that an oil field service company did a poor job of handling wastes. Storage tanks at the site reportedly leaked and overflowed and wastes from truck-washing facilities are not contained on-site. The Water Quality Bureau investigated the complaint and determined that the operation posed a threat to groundwater quality. The Water Quality Bureau sent the operator a letter and an application form to the company asking that they apply for a MGWPCS permit and permission to store wastes on-site. No response was received from the company.

Monitoring to determine water quality degradation or follow-up inspection have not been conducted by the Water Quality Bureau.

Complaint #12:

Date: February 14, 1985
Location: Sec. 36, T. 34 N., R. 2 W., Toole County
Sec. 36, T. 34 N., R. 3 W., Toole County

Description: U.S. Soil Conservation Service (SCS) staff reported that brackish water was flowing out of two abandoned oil wells. The water flowed on the surface and contaminated the soil in the vicinity of each well. SCS staff further investigated the problems, but details on corrective measures taken at each site are unknown.

Complaint #13:

Date: January 23, 1985
Location: T. 34 N., R. 3 W., Toole County

Description: A citizen complained to the Water Quality Bureau about a temporarily abandoned oil well that was discharging water on his property. Water Quality Bureau personnel inspected the site and determined that water from the well flowed into a natural depression and created a pond. The Water Quality Bureau asked the oil company to secure a written agreement from the landowner that the water would be beneficially reused for stock purposes and obtained the necessary permits. The landowner did not want the water so the oil company reinjected the water to the ground.

Complaint #14:

Date: November 20, 1984
Location: Sec. 7, T. 34 N., R. 34 N., Toole County

Description: A landowner complained to the Water Quality Bureau about a discharge of produced water on his property. The oil company had applied for a MPDES permit to discharge the water for beneficial use, but the landowner did not want to reuse the produced water so a permit could not be issued. The Water Quality Bureau wrote a letter requesting the oil company to cease the discharge.

Complaint #15:

Date: May 16, 1984
Location: Sec. 22, T. 17 N., R. 6 W., Lewis & Clark County

Description: DFWP staff reported to the Water Quality Bureau that a reserve pit liner associated with an oil well being drilled at the above location was torn and the pit was leaking. Water Quality Bureau staff inspected the site and discovered that the liner had slumped and torn in a few places but was not overflowing. Exposed edges of the liner were held down with cables to prevent it from ballooning in windy conditions.

The site was located 600 feet from a tributary to Big Skunk Creek. Samples of water collected from the creek above and below the site did not show any contamination during testing. The Water Quality Bureau inspector asked the drill foreman to modify the liner to eliminate the chance of tears and leakage.

Complaint #16:

Date: May 16, 1983
Location: Sec. 11, R. 23 N., T. 59 E., Richland County

Description: A citizen sent a letter and a sample of his well water to the Water Quality Bureau for analysis. THe citizen was concerned that an oil well drilled would contaminate his well water 350 feet away. He complained that the site had been reclaimed; however, wastes from the drilling operation were buried on-site. He also complained that his well water had a strong chemical

taste and odor. The well water had been analyzed in March 1981, prior to the initiation of oil well drilling. The later sample from the well was taken after completion of the oil well and did not show any significant increase in chemical constituents.

Complaint #17:

Date: May 5, 1983
Location: Sec. 32, T. 35 N., R. 1 W., Toole County

Description: A citizen complained to the Water Quality Bureau about an oil company that was discharging produced water on to his property. Water Quality Bureau personnel inspected the site which consists of several evaporation ponds that collect produced water from oil wells. When the ponds are full, the company siphoned liquid from the pond on to the citizens property. No discharge was occurring at the time of the inspection, but siphon hoses were present and erosion patterns indicated discharges had occurred. No water quality impacts were noted but use of the land was impaired. The oil company was told to cease the discharge or obtain a MPDES permit. Follow-up monitoring was not conducted.

THE NEW NEXICO GUIDELINES FOR LINING EVAPORATION PITS CAN BE FOUND ON PAGE 247

TECHNICAL APPENDIX 4
AIR QUALITY

INTRODUCTION

With the adoption of the Clean Air Act, EPA divided Montana into five geographical regions (Figure 4-1). Each of these Air Quality Control Regions (AQCRs) contains distinct meteorological patterns, topography, and industrial influences that would affect the emission of air contaminants from oil and gas operations. Table 4-1 summarizes the important characteristics of each region important to oil and gas drilling and production.

Terrain surrounding pollution sources greatly influences the impact of emissions. Topographic features such as mountains, valleys, or river drainages can combine to severely restrict or greatly enhance the dispersion capacity of a given airshed. These effects are highly localized and often determine how much air quality degradation may occur.

Air pollution is controlled through ambient air quality and emission standards and permit requirements established under the federal Clean Air Act and the Montana Clean Air Act (DHES 1980). There are two kinds of air quality standards. Primary standards are established at levels believed to protect human health. Secondary standards are set at levels designed to protect property, livestock, and vegetation from adverse effects of air pollutants. Montana has assumed primacy from EPA for the implementation of federal air quality programs. In many cases, Montana has adopted federal ambient air standards but also has established stricter Montana air quality standards for some pollutants. Table 4-2 lists the various state and federal standards that apply in Montana. Normally, an air quality permit is required whenever 25 tons per year of any pollutant will be emitted.

One of the most significant requirements of the federal act was to classify areas of the state according to whether they meet the National Ambient Air Quality Standards (NAAQS). While EPA and DHES have classified areas of the state based on criteria pollutants, many of these are not concerns for oil and gas development. Based on past sulfur dioxide emissions, areas of Yellowstone County around the refineries in Laurel have been deemed nonattainment, although revision of that classification is possible in the near future based on improvements recorded through ambient air monitoring. Attainment for particulates is the most likely classification of concern for oil and gas development at this time. The U.S. Environmental Protection Agency (EPA) promulgated new ambient air quality standards for dust and other particulate matter suspended in the air (EPA 1986a and b, 1987b). The new standards changed the focus from the total amount of suspended particulates (TSP) to smaller inhalable particles known as PM-10 (particles with an aerodynamic diameter less than 10 microns capable of entering small air passages in the lungs). As a result, EPA and DHES have placed each Montana community into one of three groups based upon the probability of exceeding these new standards (See Table 4-3).

Particulate emissions tend to be a more prevalent problem with large stationary emission sources or along frequently traveled thoroughfares in

FIGURE 4–1
MONTANA AIR QUALITY CONTROL REGIONS

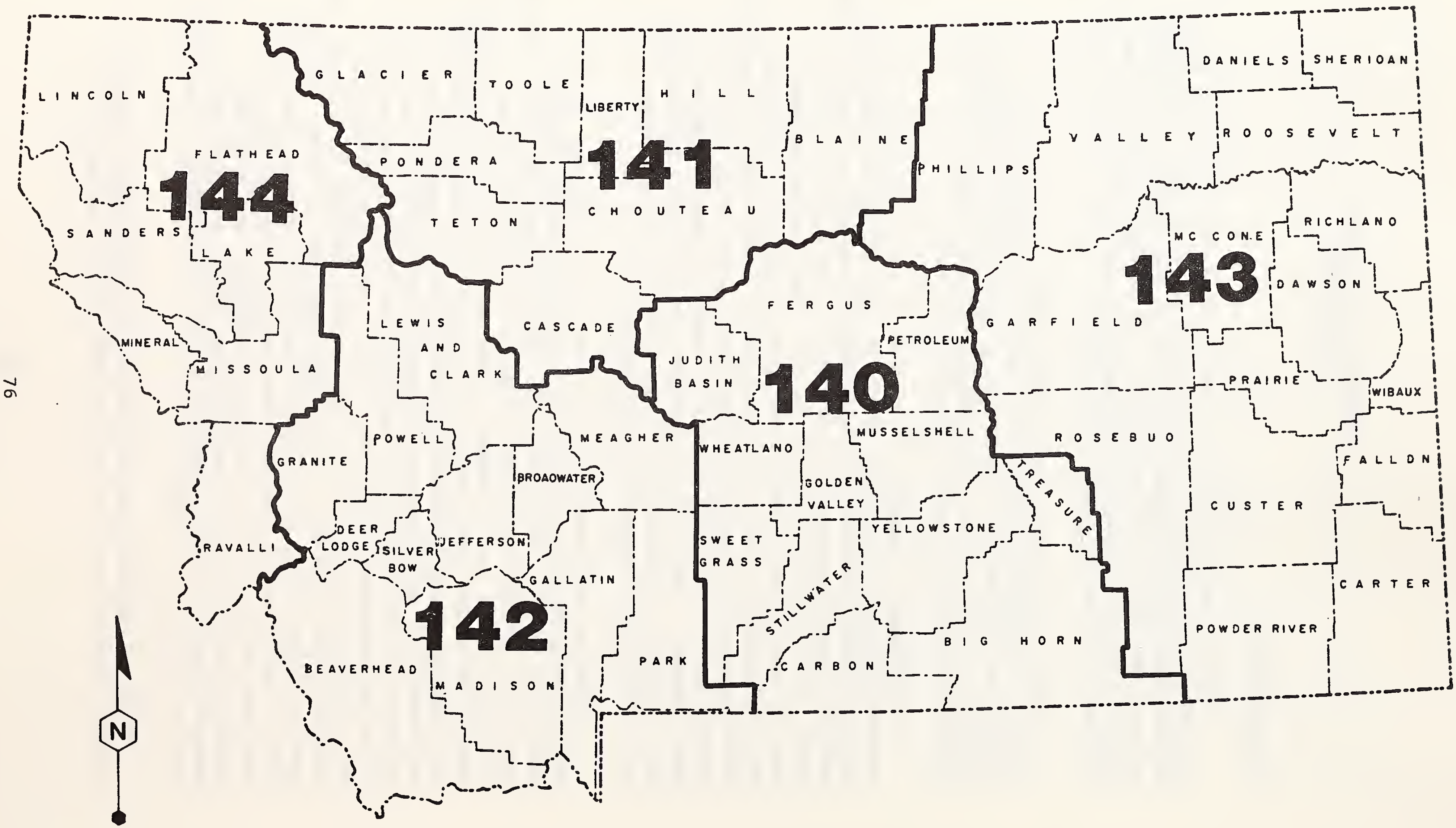


Table 4-1. Characteristics of Montana Air Quality Regions.

AQCR	Topography	Wind Patterns	Temperature Inversions	Pop.	Oil and Gas Pollution Sources
South Central (AQCR 140)	Diverse terrain, both mountains and plains.	Variable with direction and speed affected by terrain.	Common but variable in region. In mountainous valley areas, inversions strong, deep and can persist for several days in fall and winter. In plains, often weak and of short duration (12 hours).	174,000 (21%)	Three oil refineries in Yellowstone County.
North Central (AQCR 141)	Plains with isolated mountains.	Persistent and strong.	Frequent near mountains but usually shallow and of short duration (12 hours).	142,400	Cascade County - oil refinery. Glacier County - two gas sweetening.
Southwestern (AQCR 142)	Mountains surrounding broad valleys.	Generally westerly across north-south valleys.	Frequent in valleys and can persist for days with occasional deep and very strong inversions.	189,300 (23.1%)	No significant sources at present.
Eastern (AQCR 143)	Plains.	Generally westerly.	Frequent but shallow and short-lived.	100,000 (12.2%)	Richland County - two gas sweetening plants, oil wells. Roosevelt County - oil refinery, oil well flares, and vents.
Northwestern (AQCR 144)	Mountains with narrow valleys.	Strong Pacific influences, westerly winds over valleys.	Frequent in valleys. Severe and deep during fall and winter, persisting for several days.	212,300 (25.9%)	None at present.

Table 4-2. Montana and National Air Quality Standards.

Pollutant	Montana Standard	Federal Primary Standard	Federal Secondary Standard
Deeply inhalable particulates (PM-10+)	50 ug/m^3 annual average 150 ug/m^3 24-hr average*	50 ug/m^3 annual average 150 ug/m^3 24-hr average*	None
Sulfur Dioxide	0.02 ppm annual average 0.10 ppm 24-hr average* 0.50 ppm 1-hr average**	0.03 ppm annual average 0.14 ppm 24-hr average*	0.5 ppm 3-24 average*
Carbon Monoxide	9 ppm 8-hr average*	9 ppm 8-hr average*	9 ppm 8-hr average*
Nitrogen Dioxide	0.05 ppm annual average 0.30 ppm hourly average*	0.05 ppm annual average	0.05 ppm annual average
Photochemical Oxidants (ozone)	0.10 hourly average*	0.12 ppm 1-hr average*	0.12 ppm 1-hr average*
Lead	1.5 ug/m^3 90-day average	1.5 ug/m^3 calendar quarter average	None
Foliar Fluoride	35 ug/g grazing season average 50 ug/g monthly average	None	None
Hydrogen Sulfide	0.05 ppm hourly average*	None	None
Settled Particulate (dustfall)	10 mg/m^2 30-day average	None	None
Visibility	Particle scattering coefficient of $3x10^{-5}$ per meter annual average***	None	None

Key: PM10 = particulate matter with an aerodynamic diameter less than 10 microns.
ug/m^3 = micrograms pollutant per cubic meter of sampled air.
ppm = parts pollutant per million parts of sampled air.
+Statistical standards based on three years of data.
*Not to be exceeded more than once per year.
**Not to be exceeded more than 18 times per year.
***Applies to PSD mandatory Class I areas.
Source: ARM 16.8.101 through 1602

towns and cities. However, TSP/PM-10 problems could result from oil and gas exploration, particularly with the development of a large field in an area susceptible to meteorological inversions. The likelihood of long-term TSP/PM-10 problems would become extremely remote after the development phase.

Table 4-3. PM-10 Groupings and State Implementation Plan Requirements.

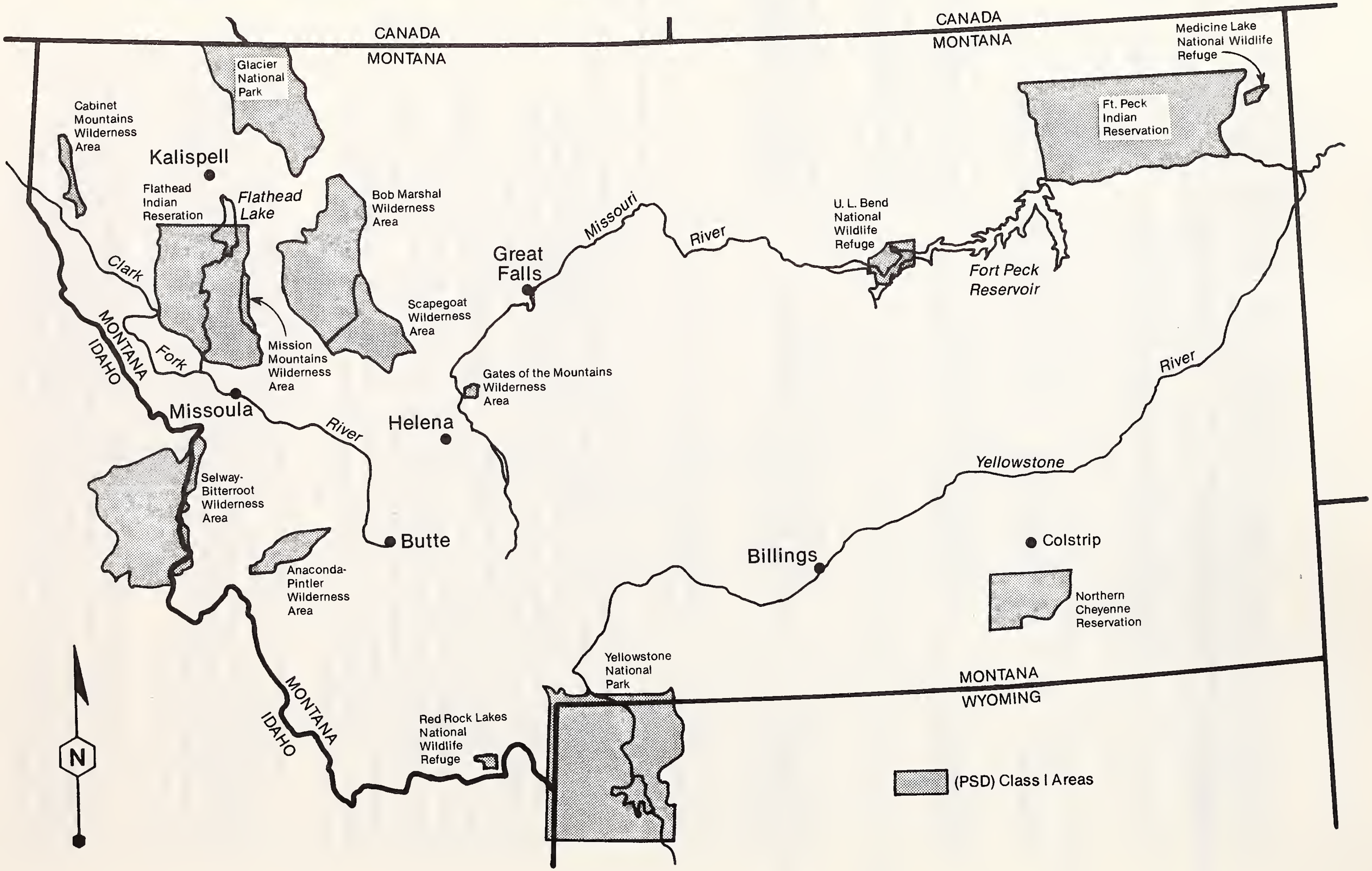
Grouping	Communities	Implementation Plan Requirements
I (Likely to violate standards)	Libby, Kalispell, Polson, Ronan, Missoula, Butte, Lame Deer, and Columbia Falls	1. Daily PM-10 monitoring 2. Develop control plan by May 1, 1988 3. Implement control plan within 3 years after EPA approval
II (May violate standards) area	Eureka, Columbia Falls, Thompson Falls, Anaconda, Helena, and Hays	1. Every other day monitoring 2. Commit to determining the compliance status of the
III (In attainment)	Rest of state	

Another important aspect of the federal act was the Prevention of Significant Deterioration (PSD) requirements that set limits for increases in ambient pollution levels and established a system for preconstruction review of new major air pollution sources. Three PSD classes have been established. In general, Class I is designed for "pristine" areas where almost any deterioration would be a significant change. Congress established several types of mandatory Class I areas. These mandatory areas include international parks, wilderness areas larger than 5,000 acres, national memorial parks larger than 5,000 acres, and existing national parks larger than 6,000 acres. Class I areas in Montana are listed in Table 4-4 and shown in Figure 4-2. The remainder of Montana is Class II and allows moderate but well-controlled growth. A PSD permit is required when emissions are likely to be 250 tons or more of a pollutant.

The increments are shown in Table 4-5. Note that the PSD increments are much smaller than corresponding national and state standards; therefore, the increments are often more limiting than the standards in determining the size of new projects that may be built. Annual average increments cannot legally be exceeded. However, short-term increments are allowed to be exceeded once per year in all areas.

A more restrictive air quality permit known as Prevention of Significant Deterioration (PSD) would be required for sources emitting 250 tons or more of a pollutant in a year. Air quality increments established under PSD regulations in Montana restrict the extent to which pollution sources can contaminate the air with sulfur dioxide and total suspended particulates. PSD

FIGURE 4-2
MONTANA PREVENTION OF SIGNIFICANT DETERIORATION (PSD) CLASS I AREAS



increments apply to routinely operating sources such as gas treatment plants or individual wells. They do not apply to temporary sources as defined by ARM 16.8.910 through 943 which "typically include, but are not limited to, emissions from a pilot plant, a portable facility, and construction or exploration activities." Examples of temporary sources include the construction of oil and gas drilling locations, pipelines, and the drilling operations themselves.

Table 4-4. Federal Class I areas in Montana.

Area	Location
Glacier National Park	NE of Kalispell
Yellowstone National Park	S Bozeman
Bob Marshall Wilderness Area	SE Kalispell
Anaconda-Pintlar Wilderness Area	SW Anaconda
Selway-Bitterroot Wilderness Area	W Hamilton
Cabinet Mountains Wilderness Area	S Libby
Scapegoat Wilderness Area	NW Helena
Gates of the Mountains Wilderness Area	NE Helena
Mission Mountains Wilderness Area	SE Polson
Red Rock Lakes National Wildlife Refuge	S Virginia City
Medicine Lake National Wildlife Refuge	S Plentywood
U.L. Bend National Wildlife Refuge	SW Glasgow
Northern Cheyenne Reservation	SE Hardin
Flathead Indian Reservation	Near Polson and Ronan
Fort Peck Indian Reservation	N Wolf Point

Table 4-5. Federal Prevention of Significant Deterioration Allowable Increments.

Particulates	I	II	III	Not to exceed
Annual geo. mean	5	19	37	75
Maximum 24-hour	10	37	75	150
Sulfur dioxide				
Annual arith. mean	2	20	40	80
Maximum 24-hour	5	91	182	365
Maximum 3-hour	25	512	700	1300

AIR POLLUTION DEFINITIONS

Sulfur Dioxide - Sulfur dioxide is released by the burning of fossil fuels such as coal or oil and the smelting of metal ores. The pollutant causes significant loss in crop yield, corrodes metals, reduces visibility, and irritates eyes, nose, throat, and lungs.

Particulate Matter - particulate matter can be generated from natural sources such as forest fires and erosion, or result from automobiles, industrial processes, unpaved roads, agriculture, construction, and other human activities. These tiny particles can damage paint, reduce visibility, and carry poisonous chemicals into the lungs, causing cellular damage.

Carbon Monoxide - Carbon monoxide is a by-product of incomplete combustion. The most notorious source is the automobile. In small amounts, this odorless gas can cause headaches, dizziness, fatigue, and slow reactions. It can be especially dangerous for people with heart disease. In larger amounts it can cause death.

Photochemical Oxidants - Photochemical oxidants, mainly ozone, are produced in the atmosphere when combustion wastes from gasoline and other fuels, such as hydrocarbons and nitrogen oxides, are exposed to sunlight. Oxidants irritate the eyes, nose, and throat, make breathing difficult, reduce visibility, and damage vegetation.

Hydrocarbons - Hydrocarbons are unburned chemicals from the combustion or evaporation of organic compounds. Automobile exhaust and open-air storage of petroleum products are common sources of hydrocarbons. They cause vegetation damage and contribute to photochemical oxidants.

Nitrogen Oxides - Nitrogen oxides usually originate in high-temperature combustion, such as in diesel engines. They are a component of photochemical oxidants, cause an unpleasant smelling brown haze, and irritate the nose and throat.

Fluoride - Fluorides are generated in the production of aluminum, glass, brick, fertilizer, and oil. Severe fluoride pollution can cause bone deformities and vegetation damage.

Lead - Lead in the air is generally the result of automobiles and ore smelters. Physical problems caused by lead in the body include gastrointestinal cramps, central nervous system effects, kidney disease, and anemia.

Hydrogen Sulfide - Sources of hydrogen sulfide, the "rotten egg" pollutant, include sewage treatment, petroleum production, and the manufacture of kraft pulp and paper. The pollutant can damage paint, tarnish copper, injure vegetation, produce a loss of the sense of smell, cause severe respiratory tract irritation, and in large doses, cause death.

Visibility - Visibility reductions relate to the amounts of particulates, aerosols, and gases in the atmosphere.

HEALTH CONSEQUENCES OF VARIOUS POLLUTANTS

In 1980, DHES completed a draft and final EIS on ambient air quality standards. This document contained a review of health effects associated with a wide range of pollutants, and established standards for protecting air quality in Montana. This material was reviewed and recent technical literature and studies regarding various pollutants was evaluated to present a current discussion of health effects. Several sources were reviewed,

including reports by Lawrence Livermore National Laboratories and recent studies done by EPA as part of their periodic review of various federal air quality standards. The results of this evaluation are summarized here.

Carbon Monoxide - CO

Carbon monoxide is a byproduct of incomplete combustion of organic fuels. In small amounts, this odorless gas can cause headaches, dizziness, fatigue, and slow human reactions. It can be especially dangerous for people who have heart disease. In large quantities, this pollutant can cause death. Table 4-6 lists levels of concentrations known to cause various symptoms. During oil and gas operations, the largest sources are gasoline and diesel engines. Smaller amounts of carbon monoxide also can be produced when natural and associated gas are burned on location (on-lease use). Such sources are flares and heater-treater units, and other ancillary equipment.

Table 4-6. United States Ambient Air Quality Criteria for Carbon Monoxide.

Percent of carboxyhemoglobin in blood (CoHb)	Concentration level in the air	Human symptoms associated with this CoHb level
80	497	Death
60	372	Loss of consciousness; death if exposure is continued
40	247	Collapse on exercise; confusion
30	134	Headache, fatigue; judgment disturbed
20	122	Cardiovascular damage; electrocardiographic abnormalities
5	28	Decline (linear with increasing CoHb level) in maximal oxygen uptake of healthy young men undergoing strenuous exercise; decrements in visual perception, manual dexterity, and performance of complex sensorimotor tasks
4	22	Decrements in vigilance (i.e. ability to detect small changes in one's environment that occur at unpredictable times); decreased exercise performance in both healthy persons and those with chronic obstructive pulmonary disease
2.5	13	Aggravation of cardiovascular disease (i.e. decreased exercise capacity in patients with angina pectoris, intermittent claudication, or peripheral arteriosclerosis)

Sources: Y. Henderson and H.W. Haggard, "Noxious Gases." Chemical Catalog Co., New York 1927. United States Environmental Protection Agency, Research Triangle Park, NC; Air Quality Criteria for Carbon Monoxide (preprint), EAP-600/8-79-022, October 1979, special series in Stern et al. 1984.

Carbon Dioxide - CO_2

Carbon dioxide is a respiratory stimulant as well as asphyxiant. Inhalation of air containing 50,000 ppm produces strong respiratory stimulation that may be accompanied by headache, rapid heart beat, sweating, shortness of breath, and dizziness. Unconsciousness occurs after a few minutes' exposure to concentrations of 70,000-100,000 ppm. The normal atmospheric concentration of carbon dioxide is about 320 ppm (Layton et al. 1983). Carbon dioxide is a component of gas and associated gas produced from

some Montana oil and gas fields. It can be released as a result of well testing procedures, venting of gas, or during a well blowout. Carbon dioxide is not considered a significant health hazard because of the high concentrations needed to affect human health. However, because it will not burn, carbon dioxide can cause practical problems for oil and gas operations when flaring of gas is required. Gas containing moderate to large amounts of carbon monoxide will either not burn completely without the addition of other more flammable gases or not burn at all.

Odorous Sulfur Compounds

These sulfur compounds are often considered a nuisance because of odors produced when in low concentrations in the air. some compounds like hydrogen sulfide can be hazardous when present at greater concentrations.

Minor amounts of most odorous gas other than hydrogen sulfide usually are present in oil and gas development. Odorous sulfur compounds can be grouped into either total reduced sulfur (TRS) compounds or partially reduced sulfur. TRS compounds are highly odorous. These compounds may be encountered during any phase of drilling, production, or storage operations of oil and gas in sour formations. The following are lists of odorous sulfur compounds:

<u>Total Reduced Sulfur - TRS</u>

1. Hydrogen Sulfide
2. Dimethyl Sulfide
3. Dimethyl Disulfide
4. Methyl Mercaptan

<u>Partially Reduced Sulfur</u>

1. Carbonyl Sulfide
2. Carbon Disulfide

A gas analysis must be performed to determine the content of these compounds for any given well.

Hydrogen Sulfide Exposure

Table 4-7 shows symptoms workers experienced based on three studies of "over-exposure" to unspecified levels of hydrogen sulfide. The data reported by Kleinfield et al. (1964) were based on information supplied by workers after a single accidental gas release at a chemical plant. The symptoms reported by Poda (1966) and Burnett et al. (1977) were based on multiple exposures at a pilot plant producing heavy water and at oil and gas facilities in Alberta, respectively. Victims of acute intoxication normally make complete recoveries without lingering symptoms or subsequent problems (LLNL 1983); however, some acute exposures have also caused death.

Table 4-7. Percent of Individuals Exhibiting Various Symptoms Following Occupational Exposures to Hydrogen Sulfide.

	Percent exhibiting symptoms in each exposure study*		
Symptom	Kleinfeld et al.	Poda	Burnett et al.
Dizziness	28	22	--[a]
Weakness	15	27	4[b](4)[c]
Nausea	13	24	13(22)
Headache	12	21	9(16)
Loss of consciousness	12	80	74(16)
Behavioral responses[d]	10	17	17(29)
Eye inflammation	2	2	5(11)
Number exposed	92	193	220

* Percentages are based on three separate exposure studies.
[a] Not defined as a separate category.
[b] Percent observed at accident site.
[c] Percent observed at emergency room is in parentheses.
[d] Behavioral symptoms include confusion, agitation, nervousness, and somnolence.
Source: Kleinfeld et al. 1984 in Layton & Cedarwell 1987.

Based on a major review of available data concerning hydrogen sulfide-related health effects, Lawrence Livermore National Laboratory (Layton et al. 1983) found that only two incidents involving accidental releases of hydrogen sulfide from sour gas facilities have caused deaths of residents. One accident occurred at Poza Rica, Mexico in 1950 at a gas purification plant where a malfunctioning flare caused the deaths of 22 people. The other incident involved a gas injection well near Denver City, Texas where nine people died due to gas exposure when a wellhead failed.

LLNL also reviewed literature on chronic hydrogen sulfide toxicity and found that there is a lack of consensus about its existence as a distinct pathological entity. Symptoms reported as a result of prolonged exposure to concentrations at or below 100 parts per million have included fatigue, behavioral changes, gastrointestinal disturbances, cold sweats, headache, and slow heart rate. A report by Vigil (1979) indicated that conclusive research on this question is hampered by a lack of "objective" symptoms and the difficulty of isolating the effects of hydrogen sulfide from other factors even in a work environment. The American Petroleum Institute has indicated that "(r)epeated exposures to low concentrations (10-50 ppm) that do not produce effects initially can eventually lead to irritation if the exposures are frequent" (1987c).

Layton et al. (1983) reported on a case that occurred in Alton, Illinois when hydrogen sulfide was emitted from a disposal lagoon that was used to process wastes from a box factory. Ambient concentrations ranged from below 0.025 ppm to over 1.0 ppm. Health-related complaints of area residents included odor annoyance, respiratory problems (e.g., labored breathing) and nausea. In another situation at Terre Haute, Indiana, also involving a lagoon used for industrial waste treatment, concentrations of hydrogen sulfide ranged

from about 0.02 to 0.3 ppm. Health effects included nausea, loss of sleep, shortness of breath, and headaches.

Residents living near Shell Canada's Waterton gas processing plant north of Waterton Lakes National Park were evaluated to compare the incidence of a variety of health problems in that area with those of Albertans living in demographically similar areas (McGill Inter-University Research Group 1986). The Shell gas plant produces approximately 425 million cubic feet of raw gas per day, with a hydrogen sulfide concentration of about 15 percent by volume (i.e., 15,000 parts per million). Residents were tested for incidence of cancer, birth risks, presence of trace metals, lung function, and other health effects. After a year of testing, the researchers concluded that "(f)or all the foregoing concerns the investigators have not detected objective evidence to perpetuate the concerns. The investigators are confident of the scientific basis of that reassurance. With respect to symptoms or how people feel concerning possible contamination of their environment, there is a small difference suggesting greater concern and more awareness of one's health and one's sensations among residents in the (area adjacent to the plant).... The investigators recommend that further clinical, epidemiologic or demographic studies involving new data collection on the field not be done."

Volatile Organic Compounds - VOCs

VOCs are precursory compounds that play a role in the formation of photochemical oxidants like ozone. The Air Quality Bureau has determined that VOC emissions from mobile sources such as light duty vehicles and diesel engines on drilling rigs are not significant enough to warrant control measures. Similarly, utilization of natural or associated gas for on-location use by heater-treaters or other equipment including flares are likewise not significant sources of VOCs during production activities.

The greatest source of VOCs from oil wells is from the bulk storage and transportation of products. During load-out of crude oil, condensates, and water, tank vapors are emitted due to repetitive emptying and subsequent filling of storage tanks and are termed "working losses." The fixed roof tank is the least expensive to construct and generally is considered the minimum acceptable equipment for storage of petroleum liquids. Fixed roof tanks are commonly used in Montana oil fields. They are equipped with a pressure/vacuum vent that allows them to operate at a slight internal pressure or vacuum to prevent release of vapors during very small changes in temperature, pressure or liquid level. Fugitive vapor releases from storage tanks usually occur from faulty pressure/vacuum valves and open gauge or thief hatches.

IMPACTS - ASSESSMENT ON A REGIONAL OR LOCAL LEVEL

One of the most important influences on the severity or seriousness of air pollution is the meteorology of the area surrounding an emission source. The dispersion of a pollutant in the atmosphere is the result of three dominant mechanisms: (1) the general mean air motion that transports the pollutant downwind, (2) the turbulent velocity fluctuations that disperse pollutants in all directions; and (3) mass diffusion due to concentration gradients. In addition, the general aerodynamic characteristics of particles,

such as size, shape and weight affect the rate at which they settle to the ground or are buoyed upward.

The assessment of probable impacts includes many considerations, such as meteorological conditions, terrain features, and the amounts of emissions from the source and from nearby sources. The magnitude of development in a given area will largely determine the degree of air quality degradation. Where oil and gas development is sparse and sour gas is not encountered, the impacts of any well or field are likely to be minimal. If the development involves sour gas reservoirs, then both short- and long-term significant impacts are more likely to occur.

Modeling

Potential air pollution impact usually is estimated through the use of air quality simulation models. A wide variety of models are available. They usually are distinguished by type of source, pollutant, transformations and removal, distance of transport, and averaging time. Air quality models can be categorized into four generic classes: Gaussian, Numerical, Statistical or Empirical, and Physical. Within some of these classes, a large number of individual "computational algorithms" exist, each with its own specific applications. Most models are just a variation of a basic Gaussian model. In many cases, the only real difference between models is the degree or detail considered in the input or output data.

In its simplest form, a model requires two types of data inputs--information on the pollutant source or sources including pollutant emission rate, and meteorological data such as wind velocity and atmospheric stability (turbulence). The model then simulates mathematically the pollutant's transport and dispersion, and perhaps its chemical and physical transformations and removal processes. The model output is expressed as air pollutant concentration for a particular time period, usually at specific receptor locations.

Impact estimates by specific models are required to meet regulatory requirements, and they are the primary analytical tool in air quality assessments; however, air quality measurements (air monitoring) can be used to evaluate or calibrate air quality models and influence the accuracy of the assessment. Only in uncommon circumstances where available models are demonstrated to be unacceptable would the use of air quality measurements alone be suitable.

The major input components of a model consist of the source, such as emission rate, volumetric flows, release points, etc. Meteorological data specific to an area or site should be used, if available. Terrain in a given area along with source type(s) usually determines what specific model will be selected for the analysis. In some cases, background air quality measurements in an area are defined and the modeled results are compared to those measurements and considered in the impact assessment. The impact assessment looks at areas such as PSD Class I, II, III increment consumption, any violation of MAAQS/NAAQS, and where these predicted impacts will occur--for example, at some distance from the source.

An air pollution model predicts the pollutant concentrations that would result from various degrees of atmospheric stability, ranging from very stable (calm) to very windy (turbulent). The analysis will determine the "worst case" situation and predict whether significant impact, such as violation of ambient air quality standards (NAAQS/MAAQS) or PSD increment consumption, is likely to occur. The model will do this for averaging periods such as 1 hour, 3 hour, 24 hour, and annual averages.

Well Testing and Production Impacts

Drill Stem Test: Drill stem tests are performed to analyze targeted parameters such as formation pressure, fluids (oil and/or condensates) and gas yields. In addition, a sample of the formation fluids and gas is taken for hydrocarbon content and hydrogen sulfide analysis. The length of this test period is very brief, usually one to three hours duration. Under these time frames, it is highly unlikely that an air quality impact would occur unless problems developed such as a blowout condition.

Gas-Oil Ratio Tests (GOR Tests): The GOR test determines the amount of gas per barrel of oil produced. This activity must be performed and reported within 30 days of well completion. Typically, a well GOR test is conducted over a 24-hour period. During the activity, the gas is metered and recorded. If the hydrogen sulfide concentration exceeds 20 parts per million (ppm) or if the gas flow rate exceeds an average of 20 MCF per day for a period of 72 hours or more, the gas shall be burned. No variance from this rule (36.22.1221 - Burning of Waste Gas Required) is allowed without written authorization from the Board. For most wells, the short time during which this activity is conducted is not likely to trigger the requirement for an air quality permit. However, if sufficient volumes of gas with high concentrations of hydrogen sulfide are burned or flared, state or federal ambient sulfur dioxide standards can be exceeded. The meteorology at test time would determine the degree of dispersion and concentration of hydrogen sulfide or sulfur dioxide in the ambient air from any gas release.

Stabilized Production Testing: This test is similar to the GOR test in reporting, but differs in respect to test duration. This activity must be performed and reported within 60 days following the completion or recompletion of an oil well. During the 60-day period, an operator can vent or flare any quantity of gas subject to certain requirements established by the Board in 36.22.1221 - Burning of Waste Gas. In Montana, stabilized production tests are usually conducted for a 10-day period and permanent equipment is used. If daily gas production exceeds 100 MCF per day after the 60-day test period established by Rule 36.22.1215 - Stabilized Production Test and the well operator intends to flare or otherwise waste the associated gas, the Board must grant approval for this action (36.22.1220 - Associated Gas Flaring). Like the GOR test, ambient air quality standards may be violated due to excessive emission rates for either hydrogen sulfide or sulfur dioxide resulting from flaring, even though an air quality permit may not be required.

While the Board requires a gas analysis in order to grant a variance to flare more than 100 MCF per day of gas, the staff does not conduct an emission analysis to determine possible air quality impacts. No gas analysis is required by either the Board or the Air Quality Bureau prior to any of the

three tests described above. This information also is not collected for most producing wells.

Individual wells are required to obtain an air quality permit when emissions of any pollutant exceed 25 tons per year. Sulfur dioxide is the pollutant most often generated by sour wells, due to the burning of gas containing hydrogen sulfide on location, either in heater-treater units (used to separate oil and water) or by direct flaring. The relative amount of sulfur dioxide emissions from a well is a direct function of the percentage of hydrogen sulfide or other sulfur compounds in the fuel gas burned.

When burned under ideal conditions (100 percent conversion), hydrogen sulfide generates water and sulfur dioxide. Because the molecular weight of sulfur dioxide is almost twice that of hydrogen sulfide, a given amount of fuel burned will generate 1.88 times more sulfur dioxide. Figure 4-3 shows the relative amounts of sulfur dioxide generated when various volumes of gas containing concentrations of hydrogen sulfide are burned through flaring or in heater-treater units.

ESTIMATING POLLUTANT EMISSIONS

The formulas presented in the following sections can be used to calculate the emissions from oil and gas activities. Depending on the emissions calculated, a requirement to obtain an air quality permit may apply.

Particulates: PM-10

The major sources of particulates from oil and gas development include site construction activities, traffic on dirt surface access roads, and combustion of diesel-powered equipment. EPA estimates indicate diesel fuel combustion generates 33.5 pounds of particulates per 1,000 gallons, and gasoline generates 6.47 pounds of particulates per 1,000 gallons.

The following formula may be used to estimate the quantity or size of specific particulate emissions from an unpaved road, per vehicle mile traveled (VMT):

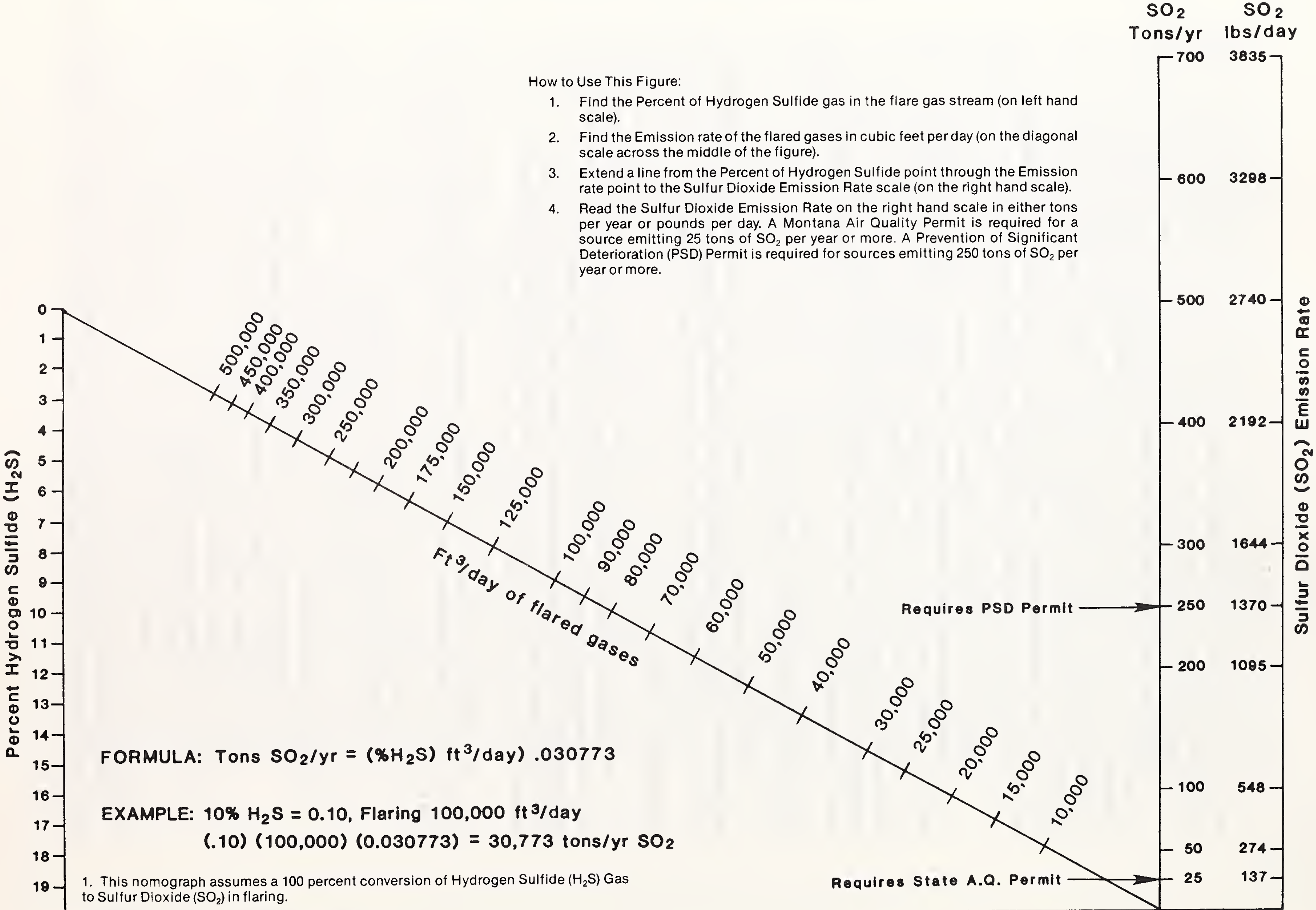
$$E\ (\text{lbs/vmt}) = K(5.9)\left(\frac{s}{12}\right)\left(\frac{S}{30}\right)\left(\frac{W}{3}\right)^{.7}\left(\frac{w}{4}\right)^{.5}\left(\frac{365-P}{365}\right)$$

Where: E = Emission factor (in pounds (lbs) per VMT (vehicle mile traveled)
K = particle size multiplier (dimensionless)
s = Silt content of road surface material (%)
S = Mean vehicle speed (mph)
W = Mean vehicle weight (tons)
w = Mean number of wheels
P = Number of days with at least 0.01 inches of precipitation per year

The particle size multiplier, K in the equation, varies with aero-dynamic particle size range in micrometers as follows:

FIGURE 4-3

SULFUR DIOXIDE EMISSIONS FROM THE FLARING OF HYDROGEN SULFIDE GASES[1]



How to Use This Figure:

1. Find the Percent of Hydrogen Sulfide gas in the flare gas stream (on left hand scale).
2. Find the Emission rate of the flared gases in cubic feet per day (on the diagonal scale across the middle of the figure).
3. Extend a line from the Percent of Hydrogen Sulfide point through the Emission rate point to the Sulfur Dioxide Emission Rate scale (on the right hand scale).
4. Read the Sulfur Dioxide Emission Rate on the right hand scale in either tons per year or pounds per day. A Montana Air Quality Permit is required for a source emitting 25 tons of SO_2 per year or more. A Prevention of Significant Deterioration (PSD) Permit is required for sources emitting 250 tons of SO_2 per year or more.

FORMULA: Tons SO_2/yr = (%H_2S) ft^3/day) .030773

EXAMPLE: 10% H_2S = 0.10, Flaring 100,000 ft^3/day
(.10) (100,000) (0.030773) = 30,773 tons/yr SO_2

1. This nomograph assumes a 100 percent conversion of Hydrogen Sulfide (H_2S) Gas to Sulfur Dioxide (SO_2) in flaring.

SOURCE: Montana Air Quality Bureau, 1982

$\leq$30 um	$\leq$15 um	$\leq$10 um	$\leq$5 um	$\leq$2.5 um
0.80	0.50	0.36	0.20	0.095

Where: LLM is particle size in micrometers

Particulate emissions vary substantially from day to day depending on the level of activity, the specific operations, and the prevailing weather. Assessing the impacts involves compilation of a particulate emission inventory from construction and operational activities and evaluating the burden of background ambient levels.

Carbon Monoxide - CO

Fuel combustion is the most likely source of carbon monoxide during oil and gas operations. Gasoline combustion produces 3,940 pounds of carbon monoxide per 1,000 gallons of fuel and diesel produces 102 pounds of carbon monoxide per 1,000 gallons of fuel burned.

Carbon monoxide emissions also would be generated by flaring gas and burning gas in heater-treater units. A typical heater-treater unit is likely to be less than 10 million BTU/hr heat input. The EPA emission factor for furnaces with this rating (<10 million BTU/hr) is 20 pounds of carbon monoxide per million cubic feet of natural or associated gas burned.

The following formula is used to calculate CO emissions from flaring and/or heater-treater combustion.

Where: E = Carbon monoxide emission rate (tons/year)

20 lbs/10^6 cubic feet, emission factor for CO

$$E = \left(\frac{\text{MCF}}{\text{day}}\right)\left(\frac{1000\ \text{CF}}{\text{MCF}}\right)\left(\frac{20\ \text{lbs CO}}{10^6\ \text{CF}}\right)\left(\frac{\text{Days Operation}}{\text{Year}}\right)\left(\frac{\text{Ton}}{2000\ \text{lbs}}\right)$$

Nitrogen Oxides - NOx

Nitrogen oxides (NOx) mainly originate in high temperature combustion processes, such as the operation of diesel engines. Drilling operations involve use of various diesel and gasoline engines.

The EPA data indicate that gasoline-fired engines have an emission factor of 102 pounds of nitrogen oxides per 1,000 gallons of fuel burned and diesel-powered industrial equipment (engines) emit 469 pounds of nitrogen oxides per 1,000 gallons.

Nitrogen oxide emissions are normally expressed as nitrogen dioxide (NO_2) and are estimated on the basis of the amount of diesel fuel consumed. The following example is used to calculate NO_2 emissions:

$$\underset{\text{(tons/year)}}{NO_2\ \text{Emissions}} = \frac{469\ \text{pounds}\ NO_2}{1000\ \text{gallons burned}} \times \frac{\text{Total gallons burned}}{\text{Yearly}} \times \frac{\text{Tons}}{2000\ \text{lbs}}$$

Drilling rigs typically may contain as many as three diesel-electric engines ranging from 800-2,000 total horsepower. Diesel-powered drilling rigs producing more than 100 tons pr year of any pollutant must obtain a permit under Montana air quality regulations. A permit an be obtained by completing necessary application forms and submitting them to the nearest office of the Air Quality Bureau.

Sulfur Dioxide - SO_2

Sulfur dioxide emissions result from the burning of fossil fuels containing sulfur. Combustion of hydrogen sulfide produces sulfur dioxide. Some sulfur dioxide is emitted by the combustion of gasoline and diesel fuel. Normal oil and gas well operations emit varying amounts of this pollutant from fuel combustion.

EPA says that gasoline-fired engines emit 5.31 pounds of sulfur dioxide per 1,000 gallons burned, and diesel engines emit 31.2 pounds per 1,000 gallons. The major source of sulfur dioxide during oil and gas development occurs when sour gas is burned on location, either in the heater-treater unit or by flaring. The amount of sulfur dioxide emissions from a source is proportional to the percentage of sulfur in the fuel burned. Sulfur dioxide emissions from an oil or gas well can be predicted with the following formula:

$$E = (0.00084)(R)(T)(\%H_2S)$$

Where E = sulfur dioxide emission rate (tons/year)

R = The average daily amount of gas burned, incinerated and/or flared (thousand cubic feet per day - MCFD) based upon a 30-day period. The 30-day period must be the last 30 operating days of a 180-day period following the completion or recompletion of a well.

T = Days of operation per year (day/year)

$\%H_2S$ = Mole percent hydrogen sulfide content as determined by most recent gas analysis.

0.00084 = Emission constant for converting H_2S to SO_2

$\frac{MCF}{Day}$ = Well gas flared or used on location

The derived formula is as follows:

$$E = \left(\frac{MCF}{Day}\right)\left(\frac{1000\ CF}{MCF}\right)\left(\frac{\%\ H2S}{100}\right)\left(\frac{LB - Mole}{379.5\ CF^*}\right)\left(\frac{64.06\ LB\ SO2}{LB - Mole}\right)\left(\frac{Days}{Year}\right)\left(\frac{Ton}{2000\ LBS}\right)$$

$$SO_2\ (Tons/Year),\ E = 0.00084\ \frac{MCF}{Day}\ \frac{Days\ Operation}{Year}\ \frac{\%\ H2S}{100}$$

*CF at standard pressure and 60^oF

Volatile Organic Compounds (VOCs)

VOCs are organic compounds that evaporate readily at normal temperatures. The most likely source of these pollutants from oil and gas operations is from bulk storage and transportation of liquid hydrocarbon products such as crude oil, condensates, and distillates. Losses to the atmosphere normally occur due to fugitive emissions from bulk storage tanks, associated pipelines,

valves, and pumps. These emissions also occur due to "working and breathing" losses. working losses occur during filling and emptying of storage tanks, and breathing losses usually result from expansion and contraction of oil and gas as a result of changes in temperature and barometric pressure. Losses during filling result when the pressure inside a tank exceeds the capacity of the relief valves and vapors are allowed to escape. Emptying loss occurs when air drawn into the tank during liquid removal becomes saturated with organic vapor and expands until it exceeds the capacity of the tank and begins escaping.

VOC emissions also can occur when wells flare gas. Also, other equipment such as heater-treater units that use well gas for fuel must be considered. EPA estimates that 2.7 pounds of methane volatile organics that are emitted per million cubic feet of gas burned. For nonmethane volatile organics, 5.3 pounds are emitted per million cubic feet burned. VOCs also are emitted as exhaust fumes from combustion of diesel fuel and gasoline. The estimates indicate that 132 pounds of VOCs are emitted per 1,000 gallons of gasoline burned, and 37.5 pounds of VOCs are emitted per 1,000 gallons of diesel fuel burned.

VOCs play a role in the formation of photochemical oxidants such as ozone (O_3). It is not likely that emissions of these pollutants from sources within the oil and gas industry would violate state or federal standards for ozone.

The following equations, provided to estimate emissions, are applicable to tanks with vertical cylindrical shells and fixed roofs. These tanks must be substantially impervious to liquid and vapor and must operate approximately at atmospheric pressure.

$$L_B = 2.26 \times 10^{-2} M_V \left(\frac{P}{P_a - P} \right)^{0.68} D^{1.73} H^{0.51} T^{0.50} F_P C K_C \quad (1)$$

Where:

L_B = fixed roof breathing loss (lb/yr)

M_V = molecular weight of vapor in storage tank (lb/lb mole), see Note 1

P_A = average atmospheric pressure at tank location (psia), see Note 2

P = true vapor pressure at bulk liquid conditions (psia), see Note 2

D = tank diameter (ft)

H = average vapor space height, including roof volume correction (ft), see Note 3

T = average ambient diurnal temperature change (^0F)

F_P = paint factor (dimensionless), see Table 4-8

C = adjustment factor for small diameter tanks (dimensionless), see Figure 4-4

K_C = product factor (dimensionless), see Note 4

NOTES:

(1) The molecular weight of the vapor, M_V, can be determined by Table 4-9 for selected petroleum liquids and volatile organic liquids or by analysis of vapor samples. Where mixtures of organic liquids are stored in a tank, M_V can be estimated from the liquid composition. As an example of the latter calculation, consider a liquid known to be composed of components A and B with <u>mole fractions</u> in the liquid X_a and X_b, respectively. Given the vapor pressures of the pure components, P_a and P_b, and the molecular weights of the pure components, M_a and M_b, M_v is calculated:

$$M_v = M_a \left(\frac{P_a X_a}{P_t}\right) + M_b \left(\frac{P_b X_b}{P_t}\right)$$

where: P_t, by Raoult's law, is:

$$P_t = P_a X_a + P_b X_b$$

(2) True vapor pressures for organic liquids can be determined from Table 4-9. T_s is determined from Table 4-9, given the average annual ambient temperature, T_A, in degrees Fahrenheit. True vapor pressure is the equilibrium partial pressure exerted by a volatile organic liquid, as defined by ASTM-D-2879 or as obtained from standard reference texts. Reid vapor pressure is the absolute vapor pressure of volatile crude oil and volatile nonviscous petroleum liquids, except liquified petroleum gases, as determined by ASTM-D-323.

(3) The vapor space in a cone roof is equal in volume to a cylinder, which has the same base diameter as the cone and is one-third the height of the cone. If information is not available, assume H equals one-half tank height.

(4) For crude oil, K = 0.65. For all other organic liquids, K_C = 1.0.

Fixed roof tank working losses can be estimated from[2]:

$$L_W = 2.40 \times 10^{-5} M_V P V N K_N K_C \qquad (2)$$

Where:

L_W = fixed roof working loss (lb/year)

M_V = molecular weight of vapor in storage tank (lb/lb mole), see Note 1 to Equation 1

P = true vapor pressure at bulk liquid temperature (psia), see Note 2 to Equation 1

V = tank capacity (gal)

N = number of turnovers per year (dimensionless)

$$N = \frac{\text{Total throughput per year (gal)}}{\text{Tank capacity, V (gal)}}$$

Table 4-8. Paint Factors for Fixed Roof Tanks

Tank Color		Paint factors (F_p) Paint condition	
Roof	Shell	Good	Poor
White	White	1.00	1.15
Aluminum (specular)	White	1.04	1.18
White	Aluminum (specular)	1.16	1.24
Aluminum (specular)	Aluminum (specular	1.20	1.29
White	Aluminum (diffuse)	1.30	1.38
Aluminum (diffuse)	Aluminum (diffuse)	1.39	1.46
White	Gray	1.30	1.38
Light gray	Light gray	1.33	1.44*
Medium gray	Medium gray	1.40	1.58*

* Estimated from the ratios of the seven preceding paint factors.

SUMMARY OF COMPLAINTS FROM NEIGHBORING STATES

In 1976, EPA sponsored a study which monitored emissions from producing oil and gas wells located at Rangely Weber sand unit in Rangely, Colorado. The study conducted air sampling for pollutants such as hydrogen sulfide, sulfur dioxide, hydrocarbons, nitrogen oxides, carbon monoxide, and ozone. Also, fugitive emission losses from pumps, pipes, flanges, seals, etc. associated with rod pump wellheads, units on treater collection stations, and manifolds on collection stations were quantified. Fugitive losses (leaks) were detected in 10 percent of the units assessed. Fugitive emission rates varied from 0 to 23.5 pounds per day per site and emission factors varied from 0 to 0.72 pounds per barrel of oil. Leak rates monitored from the oil field were variable and maintenance was cited as the key to reducing fugitive emissions (Radian 1977).

This study was limited due to the fact that it was conducted for only two months--November and December 1976. Also, hydrogen sulfide content of the field ranged from 0 to 2.2 percent according to Colorado officials. The results tended to indicate that if fugitive losses are controlled, the likelihood of violations of ambient air quality standards may be low. However, the issue of nuisance odor annoyance from these fugitive losses from hydrogen sulfide and hydrocarbons was not addressed. Combustion emissions from flaring or heater-treater units were not analyzed, nor were long-term and cumulative impacts addressed by this study.

Air quality regulatory personnel from the states of Colorado, North Dakota, and Wyoming were surveyed to collect information on impacts from oil and gas drilling and production activities. A common pattern was identified among these neighboring states which parallels the situation in Montana. Even though each state has somewhat different regulatory requirements, officials

Table 4-9. Physical properties of Typical Organic Liquids

Organic liquid	Vapor molecular weight @ 60°F	Product density (d), lb/gal @ 60°F	Condensed vapor density (w), lb/gal @ 60°F	True vapor pressure in psia at: 40°F	50°F	60°F	70°F	80°F	90°F	100°F
Petroleum liquids*										
Gasoline RVP 13	62	5.6	4.9	4.7	5.7	6.9	8.3	9.9	11.7	13.8
Gasoline RVP 10	66	5.6	5.1	3.4	4.2	5.2	6.2	7.4	8.8	10.5
Gasoline RVP 7	68	5.6	5.2	2.3	2.9	3.5	4.3	5.2	6.2	7.4
Crude oil RVP 5	50	7.1	4.5	1.8	2.3	2.8	3.4	4.0	4.8	5.7
Jet naphtha (JP-4)	80	6.4	5.4	0.8	1.0	1.3	1.6	1.9	2.4	2.7
Jet kerosene	130	7.0	6.1	0.0041	0.0060	0.0085	0.011	0.015	0.021	0.029
Distillate fuel no. 2	130	7.1	6.1	0.0031	0.0045	0.0074	0.0090	0.012	0.016	0.022
Residual oil no. 6	190	7.9	6.4	0.00002	0.00003	0.00004	0.00006	0.00009	0.00013	0.00019
Volatile Organic Liquids										
Acetone	58	6.6	6.6	1.7	2.2	2.9	3.7	4.7	5.9	7.3
Acrylonitrile	53	6.8	6.8	0.8	1.0	1.4	1.8	2.4	3.1	4.0
Benzene	78	7.4	7.4	0.6	0.9	1.2	1.5	2.0	2.6	3.3
Carbon disulfide	76	10.6	10.6	3.0	3.9	4.8	6.0	7.4	9.2	11.2
Carbon tetrachloride	154	13.4	13.4	0.8	1.1	1.4	1.8	2.3	3.0	3.8
Chloroform	119	12.5	12.5	1.5	1.9	2.5	3.2	4.1	5.2	6.3
Cyclohexane	84	6.5	6.5	0.7	0.9	1.2	1.6	2.1	2.6	3.2
1,2-Dichloroethane	99	10.5	10.5	0.6	0.8	1.0	1.4	1.7	2.2	2.8
Ethylacetate	88	7.6	7.6	0.6	0.8	1.1	1.5	1.9	2.5	3.2
Ethyl alcohol	46	6.6	6.6	0.2	0.4	0.6	0.9	1.2	1.7	2.3
Isopropyl alcohol	60	6.6	6.6	0.2	0.3	0.6	0.7	0.9	1.3	1.8
Methyl alcohol	32	6.6	6.6	0.7	1.0	1.4	2.0	2.6	3.5	4.5
Methylene chloride	85	11.1	11.1	3.1	4.3	5.4	6.8	8.7	10.3	13.3
Methylethyl ketone	72	6.7	6.7	0.7	0.9	1.2	1.5	2.1	2.7	3.3
Methylmethacrylate	100	7.9	7.9	0.1	0.2	0.3	0.6	0.8	1.1	1.4
1,1,1-Trichloroethane	133	11.2	11.2	0.9	1.2	1.6	2.0	2.6	2.2	4.2
Trichloroethylene	131	12.3	12.3	0.5	0.7	0.9	1.2	1.5	2.0	2.0
Toluene	92	7.3	7.3	0.2	0.2	0.3	0.4	0.6	0.8	1.0
Vinylacetate	86	7.8	7.8	0.7	1.0	1.3	1.7	2.3	3.1	4.0

* RVP = Reid vapor pressure in psia.

from each of the states noted that nearly all complaints occurred during the production phase and almost exclusively involve sour oil, gas, and oil-gas wells. Respiratory effects and nuisance odors were the most prevalent symptoms reported. Flares, treaters, and storage tanks were the most prevalent emission sources; however, leaks from aging gas collection pipelines also were noted. Reoccurring complaints from problem sources were further noted. Late night and/or early morning hours, a calm atmosphere, and prevailing winds best characterize the conditions when effects were noticed.

MONTANA CASE STUDIES

The following case studies involve wells located in eastern Montana that produce oil and associated sour gas. Associated gas is flared and used on location to fuel heater-treater units.

Case #1

In 1981, DHES received three complaints from rural residents regarding a federal well located just north of Sidney. Table 4-10 summarizes data for the well. One resident whose home was located in a low-lying area where the gas accumulated complained of nuisance odor and annoyance and respiratory system irritation.

Table 4-10. Summary of Data for Case Study 1.

Oil produced	1,900 bbls per day
Water produced	53 bbls per da
Associated gas	
flared	144 MCF per day
heater-treater	6 MCF per day
Gas analysis	
methane	63.51%
hydrogen sulfide	14.40%
carbon dioxide	11.3%
ethane	6.84%
butane/pentanes	1.6%
other	0.15%
Sulfur emitted due to flaring in 1981	600 tons (49,336 MCF)

The producer performed an economic feasibility study for sulfur removal from the associated gas produced and deemed it too costly. A pipeline to a gas-processing facility was not yet available so the only alternative was to seek a variance to flare the gas from BLM and the Board. Upon recommendation of BLM, the producer applied for an air quality permit in July 1981 to obtain permission to flare all the associated gas produced. The permit was denied by DHES in 1982 because the computer modeling indicated that under the unfavorable meteorological conditions, the Montana 1-hour sulfur dioxide standard (0.500 ppm) would be exceeded by a factor of 95, and the 24-hour and annual Montana sulfur dioxide standards would be exceeded by factors of 118 and 12, respectively. Also, modeling indicated that 100 percent of all

applicable PSD Class II sulfur dioxide increments would be totally consumed. Installation of a gas pipeline to a sulfur removal plant enabled the well to attempt production again in 1983. Paraffin and hydrogen sulfide build-up in the gas-gathering pipelines caused problems at the gas sweetening plant which resulted in suspension of gas sales. Consequently, the well was plugged after a further request for a flaring variance and air quality permit exemption were denied.

Case #2

A more recent example of chronic hydrogen sulfide exposure of residents involved a sour oil-gas well located just northeast of the Sidney area completed in December 1986. Table 4-11 summarizes data abut the well. The well is situated in a coulee drainage about 2.7 miles away and 115 feet above a residence. A GOR test was conducted that same month, and during this test, well gas was vented to the atmosphere without being flared. The residents were fumigated with hydrogen sulfide during the GOR test. The effects, which were confirmed by a doctor, included irritation to the upper and lower respiratory tract, nausea, and headaches. Ambient measurements were not conducted at that time, but measurements taken following the filing of a complaint by the residents showed a 1-hour concentration of 0.058 ppm hydrogen sulfide, which exceeded the Montana ambient standard. The Board and DHES cooperated in shutting the well in a number of times, although problems persisted.

Table 4-11. Summary of Data for Case Study 2.

GOR test	
oil	238 bbls per day
gas	33.32 MCF per day
Associated gas	
heater-treater	9.8 MCF per day
sold	221 MCF per day
Hydrogen sulfide concentration (based on sales of gas)	17.5%
Sulfur emitted from heater-treater (191 days)	25 tons

The residents left their home on several occasions due to the effects of low levels of hydrogen sulfide exposure after the well was connected to a pipeline and gas-processing facility. Possible sources of the hydrogen sulfide included venting of gas during disposition of crude oil and produced water, winds that caused gas to escape from storage tanks, and incomplete combustion of gas because the flare attached to the storage tanks did not work consistently (Hughes 1986). Complaints from the residents continued whenever prevailing winds were from the well source or when calm periods occurred. Production records examined by DHES indicated that the well exceeded the state permitting threshold for emissions of sulfur dioxide after just 191 days of operation due to the use of associated gas in the heater-treater system.

The recommendations by DHES to the board and the producer regarding measures to correct the problems included installation of welded storage tanks, installing a vapor recovery system so working and breathing losses from tanks were not lost to the atmosphere, elevating the flare stack above ground to enhance dispersion, and using propane as a fuel source in the treater unit.

Investigation following a further complaint indicated the problem was primarily due to failure of the first vapor recovery system flare and leaky seals on the three tank hatches. When the control strategies failed, such as was the case with the vapor recovery system, the well was shut-in for repair and maintenance. The well producer conducted an ambient monitoring surveillance around the perimeter (lease area) as well as at some farther distances out. Two different monitoring sites located about 700 feet down the coulee from the well recorded hydrogen sulfide hourly concentrations with a range of 0.053 to 0.195 parts per million (ppm). A monitor placed near the residence recorded only a trace (over 0.005 ppm) of hydrogen sulfide during a two-week monitoring effort.

Case #3:

The only continuous air monitoring effort conducted around an oil-gas well in Montana was done for two oil-gas wells located in Richland County situated less than a quarter mile apart. Table 4-12 lists information regarding these wells.

Table 4-12. Summary of Data for Case Study 3.

	Well #1	Well #2
GOR test results		
oil	70 bbls/day	60 bbls per day
gas	0.861 MCF/day	0.634 MCF per day
hydrogen sulfide	17%	14.43%
Sulfur emission		
initial estimate	236 tons per year	127 tons per year
revised estimate	315.7 tons per year	168.6 tons per year
Modeling results SO2	Annual average	4 ug per m3 (0.0015 ppm)
1983	24 hour average	20-38.4 ug per m3 (0.00771 to 0.0145 ppm)
	3 hour average	153 ug per m3 (0.0587 ppm)
	1 hour average	291.1 ug per m3 (0.1114 ppm)
Corrected Model Results		
1988	Annual average	5.34 ug per m3 (0.0020 ppm)
	24 hour average	26.8 to 50.9 ug per m3 (0.0103 to 0.0195 ppm)
	3 hour average	205 ug per m3 (0.0785 ppm)
	1 hour average	390 ug per m3 (0.1493 ppm)

The wells began producing in the early 1970s. In 1983, EPA and the Air Quality Bureau conducted a survey of producing wells in Montana's Williston Basin after concern was noted over flaring (Del Green Associates, Inc. 1982).

The survey was limited in scope, relied upon voluntary compliance of the operators, and did not include follow-up. It revealed that these two wells were operating in excess of 25 tons per year due to flaring of sour gas. In 1983, the Montana Air Quality Bureau notified the producer that the wells were operating without an air quality permit. The producer hired a consultant to prepare the air quality permit application, perform modeling analyses to predict ambient sulfur dioxide impacts from flaring, and conduct air monitoring around the two wells, including continuous meteorological, sulfur dioxide, and sulfation rate surveillance (Hughes 1987a). Based on initial study results, an air quality permit was issued for each well based on installation and/or performance of the following: (1) 30-foot flare stack; (2) automatic flare ignition system; (3) automatic well shut-in system; (4) hydrogen sulfide warning system with alarms; (5) sulfation rate monitoring; (6) continuous sulfur dioxide and meteorological monitoring if sulfation rate monitoring indicated elevated readings; and (7) data reporting requirements. Following a year of sulfation rate surveillance, the Air Quality Bureau required continuous sulfur dioxide monitoring due to the elevated sulfation rate readings. (Sulfation rate is a method of determining the total available reactive sulfur compounds in the air. Measurement is achieved by exposing a reactive surface of lead peroxide for a period of approximately 30 days. This measurement, sulfation rate, is a fairly good indicator of the quantity of sulfur oxides present in the air. The advantage of this method is that numerous samples can be deployed and analyzed economically. Seven sulfation rate receptor sites were deployed around the two wells during 1984-85. Based on sulfur dioxide levels found, 14 months of continuous air monitoring was conducted.

While good correlation usually exists between actual sulfur dioxide readings and calculated sulfation rate data (Raisch and Bosehee 1987), a poor correlation was found in this case. This may suggest that the sulfur compounds reacting with the sulfation plates were not sulfur dioxide but some other sulfur compounds which would not be detected by continuous sulfur dioxide monitoring. It is believed that some of the flared hydrogen sulfide was not thoroughly oxidized to sulfur dioxide and that hydrogen sulfide and other sulfur compounds were escaping into the air. Hindsight observations indicate that continuous hydrogen sulfide monitoring also may have been warranted in this case and should be considered for future flaring permits. While there were no exceedances of the ambient sulfur dioxide standards from either of these two wells, the monitoring data indicates that the actual one and three-hour sulfur dioxide recordings exceeded the predicted concentrations. This is most likely due to a calculation error of the emission rate that was recently discovered on the permit application and modeling analysis. The actual emission rate for each well is 1.33 times greater than the rate modeled, which would have triggered the requirements for a PSD permit. The monitored sulfur dioxide data appears to fit the corrected model prediction better. Since a PSD review was not done for these wells, the potential air quality impacts regarding increment consumption cannot be determined.

All air monitoring was terminated around the subject wells in December 1986 when the producer shut in the smaller producer well and recompleted the larger producing well to another zone in the formation which contained a smaller concentration of hydrogen sulfide (about 1.0 percent). This well was then connected to a gas sweetening plant approximately 3 miles away.

Hydrogen Sulfide Wells in the Williston Basin

A recent file search of oil-gas wells producing in the Williston Basin conducted for DHES for a joint study with North Dakota revealed that of 541 well files reviewed, only eight had reported a gas analysis (U.S. BLM 1987c). A recent review of BLM leases from the Miles City district office showed that of 87 producing leases known to produce hydrogen sulfide along with hydrocarbon, only about 14 leases had information about hydrogen sulfide concentrations that could be retrieved from computer files. BLM officials admit that the system needs updating because one would have to search a lease file to determine the number of well(s) per lease and then locate a gas analysis for the given well(s) (Connell 1988).

BLM's (Montana Office) Directive Regarding Flaring and Class I Areas

BLM's Notice to Lessees - 4A (NTL-4A) regarding flaring of gases provides for the conservation of oil and gas resources and establishes the means by which operations must compensate the federal government for the full value of gas and oil if wasted by flaring or venting. Gas wells may not be flared or vented unless the well is being tested. Oil well gas may not be vented or flared unless approved in writing, based on previously submitted engineering, geologic, and economic data. From discussions with BLM officials (Kruger 1988, Rasmussen 1988, Connell 1988), venting and flaring is authorized up to the limits allowed Board rules. BLM denies applications for flaring if the review indicates air quality violations of local, federal, or state standards and PSD increments are likely. When reviewing an application to flare, a calculation of tons/year of sulfur dioxide is required. If the calculation reveals 25 tons per year or greater, a stipulation is placed on the flaring approval requiring that a state air quality permit be obtained. Permitting records indicate that only three wells since 1981 have applied for a state air quality permit. Two wells were permitted while one permit was denied by the Montana Air Quality Bureau (i.e. Case Study #1, Flared Emissions). The low number of permit applications for federal wells can be partially explained by the fact that BLM can require an operator to reduce production to levels that do not trigger the air quality permit threshold (Connell 1988). The Montana BLM office utilizes a screening method known as the "rule of thumb" for estimating impacts and the need for further analysis. If results of the screening analysis indicate possible significant impacts or violation of ambient air standards, then the appropriate air quality agency is contacted. The "rule of thumb" allows BLM to calculate:

1. whether or not a source qualifies as a PSD source;
2. whether or not a source exceeds PSD increments for sulfur dioxide or particulates;
3. whether or not a source in combination with other PSD sources in the area may contribute to the exceedance of an increment;
4. that the emission rate is known or estimated from gas analysis with well flow rate data; and
5. the distance downwind to Class I or II areas is 10 km or greater.

The "rule of thumb" does not consider or address visibility impacts which are issues at sites visible from long distances. It also should be noted that this simple analysis is only a screening technique and that further modeling

analysis may be necessary in order to develop a more accurate impact assessment.

BLM also has established criteria for other pollutants that may be emitted by wells. Table 4-13 lists pollutants and their concentration levels that trigger review and require approval by BLM.

Table 4-13. Pollutants and Their Concentration Levels which Trigger BLM Review.

	Emission Rates (tons/year)	Impact Level (ug/m3)	Averaging Period
Carbon monoxide - CO	100	575	8 hour
Nitrogen dioxide - NO^2	40	14	annual
Particulate matter - PM	25	10	24 hour
Sulfur dioxide - SO^2	40	13	24 hour
Hydrogen sulfide - H^2S	10	0.04	1 hour
Total reduced sulfur - TRS	10	10	1 hour
Reduced sulfur compounds	10	10	1 hour
Ozone - O^3	[1]a	0	1 hour

[a] 40 tons/year of volatile organic compounds (VOC's)
[b] increases in VOC emissions of 100 tons/year or more
Source: BLM Montana Office, NTL-4A attachment

To date, BLM has reviewed only emissions from flaring or venting (Connel 1988). Emissions from burning gas on lease in heater-treaters or other ancillary equipment are not generally reviewed. By definition, "beneficial purposes" under NTL-4A allows the consumption of gas on lease for the purpose of firing treaters, steam generators, and other ancillary equipment and is not considered wasteful or not considered as emissions for purposes of analysis under NTL-4A.

ECONOMICS OF HYDROGEN SULFIDE RECOVERY

In adequate concentrations and with significant volumes, the sulfur removed from hydrogen sulfide can be a valuable asset and is a marketable commodity. In amounts that are subeconomic, however, the handling and elimination of the gas are an annoyance and can contribute to higher operating costs. The United States is currently a net importer of sulfur, bringing in about 17 percent of the 11 million tons consumed annually. The increase in demand has come from the agricultural community since the recognition of sulfur as a critical soil nutrient. Fertilizer and related agricultural products account for 70 percent of all domestic consumption. That market appears to be stable over the long term.

Currently there are no commercial sources of hydrogen sulfide in Montana, but the potential for discovery and utilization of hydrogen sulfide as a resource exists. High concentrations of hydrogen sulfide and large quantities of gas are required to make sulfur recovery profitable. Even in the northwestern part of the Williston Basin where concentrations of hydrogen sulfide gas reach 35 to 40 percent in some wells, the collective volumes are

too small to warrant cost of pipelines to area sulfur plants or provide incentive for new sulfur removal plants. Some gas containing hydrogen sulfide in the Williston Basin is sent to one of several gas plants in North Dakota for processing. Those plants extract elemental sulfur as an end-product of the amine sweetening process.

Amine plants use a closed circulating system whereby mono or dielhanolamine is used to strip both hydrogen sulfide and carbon dioxide from the gas stream. The amine is circulated to a regeneration unit where it is cleaned for re-use. The hydrogen sulfide and carbon dioxide are then either burned or sent to a sulfur plant for conversion to elemental sulfur. If the carbon dioxide content is too great to flare, fuel gas may have to be added to maintain combustion to convert hydrogen sulfide to sulfur dioxide prior to venting into the atmosphere. The decision whether to flare or convert to sulfur is an economic one driven by regulatory pressure for small to medium-sized operations, and driven by commodity prices for larger-sized operations. Amine plants are economic when 2 to 3 million cubic feet of gas per day with hydrogen sulfide concentrations over 100 ppm can be processed. Sulfur plants are considered sulfur dioxide when total emissions exceed 25 tons per year and begin making a profit when they can produce 50 tons of elemental sulfur per day.

MITIGATION

VOC Mitigation

Normally, control of fugitive emissions involves minimizing leaks and spills via equipment changes, procedure changes, and improved housekeeping and maintenance practices. Vapor recovery systems work on a vacuum principal, collect tank vapors and either direct them to a flare or collection pipeline. In order for the vapor recovery system to function properly, all valves, flanges and seals must be in good working order. One other consideration in regard to fugitive tank vapor losses has to do with the color of the storage tanks. Tank color has a direct effect on the storage temperature of the product which in turn has a direct effect on volatilization of product. Tables 4-12 shows tank color and resultant effect on storage temperature. White has the least effect while black has the greatest effect. This variable is an important element used in calculating "breathing losses" from fixed roof tanks.

Carbon Dioxide Mitigation

Since all carbon monoxide is a byproduct of incomplete combustion, mitigating this pollutant may involve reducing emissions from mobile engines such as light duty gasoline-fueled vehicles. However, most sources involved with construction and predrilling activities are temporary and their emissions are limited to short periods of time. Therefore, if control strategies are required, they would be focused on minimizing short-term impacts to the 1-hour and 8-hour air quality standards. For a worst-case situation, the most stringent control strategy may involve carpooling to reduce or restrict the number of mobile sources such as light duty gasoline-fueled vehicles. On a pound per hour basis, more carbon monoxide is emitted from gasoline-fueled vehicles than from diesel vehicles. Carbon monoxide emissions from stationary sources such as drilling rig engines, flares, and treaters usually are not

substantial enough to warrant control. Proper maintenance of both gasoline and diesel-fueled engines is likewise important in minimizing exhaust emissions. Catalytic converters should be used on exhaust gas to reduce carbon monoxide emissions.

Emissions from flares and treater sources are a direct function of combustion conditions. Inadequate maintenance may result in higher than normal carbon monoxide emission rates for well site equipment. Effective inspection and maintenance programs for well site equipment should be implemented to detect aged or deteriorated components and equipment and replace them if necessary.

TECHNICAL APPENDIX 5
HEALTH AND SAFETY

The air quality impact analysis contains a discussion of the properties of various air pollutants and a review of the scientific literature on human health effects associated with certain concentrations of various gases. These effects are the basis for standards that have been adopted to regulate air quality. The discussion of health effects in this section is limited to an explanation of specific types of hazard situations; a discussion of data concerning the probability of accidents occurring, a discussion of methods used to calculate health risks, and a summary of accidents that have occurred in Alberta, Wyoming and other areas.

RELEASE OF TOXIC AND NOXIOUS GASES

There are a number of gases associated with oil and gas drilling and production that may be released in toxic or noxious concentrations as a result of accidents or equipment failure, including hydrogen sulfide, sulfur dioxide, and carbon dioxide. Exposure to these gases, especially hydrogen sulfide, has long been recognized as an occupational health hazard. The oil and gas industry, government agencies and private sector organizations have devoted considerable attention to establishment of exposure limits and safety procedures to protect workers. Where the presence of hydrogen sulfide is likely or unknown, companies may prepare contingency plans to protect the general public in the event of an emergency.

OCCUPATIONAL HEALTH EXPOSURE LIMITS

Threshold limitations for worker exposure to hydrogen sulfide and sulfur dioxide have been established by the federal Occupational Health and Safety Administration (OSHA), the American Conference of Governmental Industrial Hygienists (ACGIH), and the National Institute for Occupational Safety and Health (NIOSH). Also, the Montana Board of Health and Environmental Sciences (MBHES) has adopted rules establishing exposure limits for employees whose work place is not of sufficient size to be covered by OSHA. These thresholds are summarized in Table 5-1.

Worker exposure to concentrations over these thresholds requires use of protective breathing equipment and other safety precautions. The occupational health thresholds apply to the work place. National and state ambient air quality standards apply to areas outside the property or lease boundary or to areas to which the public has access (Raisch 1988).

OSHA has extensive regulations that address a comprehensive range of worker safety requirements (OSHA 1985). However, most of these regulations are generic and oriented toward work activities rather than toward the industry in which the activities occur. In late 1983, OSHA proposed a set of worker safety regulations specific to the oil and gas industry that have not yet been finalized. OSHA stated that its "general industry standards inadequately address the unique hazards encountered during drilling, servicing, and the performance of special services operations on oil and gas wells" (OSHA 1983b). Examples of operations and equipment hazards unique to the industry include cementing, drill stem testing, wireline operations, and

use of catheads, drawworks, and rotary tables (OSHA 1983a). Data indicates that worker injury and illness rates for oil and gas extraction and field services were two and three times higher than the private sector "all industry" rates (OSHA 1983a). These rates are similar to those for the mining and construction industries. A study of non-fatal accidents associated with oil and gas drilling and servicing indicates that two-thirds of the injuries occur during drilling operations (U.S. Bureau of Labor Statistics 1983).

To explain the background of its proposed regulations, OSHA discussed the results of several of its studies of worker fatality and accident data obtained from 1972-1981 (OSHA 1980, 1981, and 1983a). The majority of fatalities occurring between 1974 and 1978 were related to falls from the derrick or other working surfaces (75 percent) or being "struck by" or "caught in" machinery and equipment (OSHA 1980). Operational problems such as failure to observe or not tying off when on the monkeyboard or stabbing board accounted for nearly half of the fatal incidents evaluated. The other studies found that most accidents were caused by inadequate supervision (especially of new employees) and operating procedures; inadequate training; failure to use fall restraining devices and other protective equipment; rig collapse or failure; failure to lockout power sources; and failure to place guardrails to prevent falls and tripping; and covers and other devices around machinery or equipment.

BLOWOUT STATISTICS

Layton et al. (1983) reviewed data from Alberta on the causes of 83 blowouts of natural gas wells that occurred during drilling operations between 1960 and 1980 and found that 57 percent of the blowouts occurred during trips, due either to the swabbing action of the drill pipe, insufficient mud weight, failure to keep the well full of drilling fluid, or a combination of those causes. The other blowouts were triggered by the penetration of high pressure gas zones (12 percent), lost circulation (11 percent), and equipment failures combined with miscellaneous or unknown causes (10 percent). Causes of the remaining 10 percent of cases were not discussed by Layton et al.

In reviewing 43 accidental gas releases that occurred at production facilities in Alberta during the period of 1960 through 1980, Layton et al. determined that 35 percent of the releases were due to servicing operations and 30 percent to external damage such as the wellhead being run over by a moving vehicle. Miscellaneous failure of equipment such as valves or cracking of cement accounted for most of the remaining releases. Although hydrogen sulfide is highly corrosive, it was not implicated as a cause in any of the equipment failures. If a blowout occurs, it may last anywhere from less than an hour to several months.

Environmental Research and Technology (ERT) analyzed causes of pipeline leaks and ruptures in a report to the Bureau of Land Management and U.S. Forest Service for the Riley Ridge Natural Gas Project located in western Wyoming (1983). According to data from the U.S. Army Corps of Engineers (1982) and the American Gas Association (1980), the largest single cause of pipeline leaks is outside force such as from equipment operated by a party other than the pipeline operator (53 percent and 69.3 percent of total incidents reported in the two sets of data, respectively). Material defect and corrosion were the next most frequent causes (together accounting for

Table 5-1. Occupational Exposure Levels for Hydrogen Sulfide and Sulfur Dioxide.

	Parts per Million	Time/Day	Source
Hydrogen sulfide	20	ceiling concentration; no time limit	OSHA
	50	10 minute maximum and only if no other exposure	OSHA
	10	8 hour, time-weighted average (TWA)	ACGIH
	15	15 minute, TWA, up to 4 times/day	ACGIH
	10	10 minute, TWA	NIOSH
Sulfur dioxide	5	8 hour TWA	OSHA
		8 hour TWA	ACGIH
	0.5	10 hour TWA	NIOSH

Source: American Petroleum Institute 1987c

Table 5-2. Well Field Blowout Rates.

Source	Blowouts per Wells Drilled	Blowouts per Producing Well-Year
Texas[1]	1 per 270	1 per 20,000
Alberta, Canada[2]	1 per 630	1 per 3,000
Gulf of Mexico[3]	1 per 250	Not given

NOTE: A blowout is defined as any uncontrolled release of gas to the atmosphere. The average length of a blowout is three days.

1 Texas data for years 1977-1981 from David W. Layton, Lawrence Livermore National Laboratory, Livermore, CA, October 4, 1982. Blowouts per wells drilled includes dry holes.

2 Alberta, Canada data for years 1970-1980 from David W. Layton, Lawrence Livermore Laboratory, Livermore, CA, October 4, 1982. Blowouts per wells drilled includes dry holes drilled for only natural gas. If dry holes drilled in anticipation of finding oil for this period are included, Alberta's blowout rate drops to 1 per 526 wells (Layton 1985).

3 For Gulf of Mexico data. Production of Natural Gas from the Lower Mobile Bay Field, Alabama, Final Environmental Impact Statement, U.S. Army Corps of Engineers, 1982.

another 40 percent of the accidents reported by the U.S. Army Corps of Engineers and 31.4 percent by the american Gas Association).

Ruptures in pipelines aer controlled by block valves that are speced at intervals along the line. If a rupture occurs, the valves on either side of the rupture are pressure activated and closed. The atmospheric discharge decreases with time until the pressure within the pipe equals atmospheric pressure.

Blowout and Pipeline Failure Rates

Blowouts of natural gas wells may occur during either drilling or production. Data on well blowout rates in Texas, Alberta, and the Gulf of Mexico are shown in Table 5-2. Using both the Texas and Alberta data, Layton et al. (1983) calculated a blowout rate per producing well over a 20-year period and found that the geometric mean value of the rates reported in Table 4 was 1 per 3,333 wells. Based on this calculation, Layton et al. concluded that the probability of a blowout during drilling is comparable to that during the entire production or post-completion phase.

More recent data from Alberta indicate that in 1986 there were approximately 4,495 wells drilled with two blowouts, and that in 1985 there were about 8,500 wells drilled with one blowout (Energy Resources Canada Board 1987c). Among approximately 79,000 active wells in 1986 there were 16 blowouts. Only two of the 16 blowouts at active wells involved sour gas (a shut-in gas well, and a shut-in oil well). Ten of the 16 blowouts were controlled in 24 hours or less while the longest period that a well remained uncontrolled was 11 days. Equipment failure or a procedural shortcoming (e.g., lack of proper maintenance) caused 13 blowouts; two were the result of third-party damage, and for one blowout the cause was undetermined.

Table 5-3 summarizes historical data on gas pipeline failure incidents (Environmental Resources and Technology Inc. 1983b). According to personnel from the Alberta Energy Resources Conservation Board, one reason Alberta's sour gas pipeline accident rates are much lower than those for United States gas pipelines may be the additional precautions taken in protecting sour gas pipes (Energy Resources and Technology Inc. 1983b). In a separate analysis of Alberta data on pipeline ruptures, Layton et al. (1983) noted that unlike the U.S. data, the Alberta data did not include minor leaks, thus perhaps accounting for a failure frequency that was three times less for gathering lines and ten times less for transmission lines than failure rates reported in the United States.

Pipeline failure rates diminish with increasing diameter size for natural gas pipelines (de la Mare et al. 1980; Environmental Resources and Technology Inc. 1983b). Pipe of less than 6 inches in diameter represents 44 percent of failure incidents while 6 to 10 inches in diameter accounted for another 20 percent of accidents (U.S. Department of Transportation 1980). U.S. Department of Transportation (DOT) data from 1970-1973 indicated that the probability of an incident decreases as pipe size increases, varying from 0.0001 for a 6-inch line to 0.0001 for a 30-inch line (Environmental Research and Technology Inc. 1983). Large ruptures account for only 7-11 percent of all incidents (Environmental Research and Technology Inc. 1983).

Table 5-3. Gas Pipeline Incident Rates.[1]

Source	Type of Product	Accident Rate (incident per Mile/Year)
U.S. Dept. of Transportation (Office of Pipeline Safety) [2] and [3]	Natural gas /.6 x 10^{-4} or 199/2.6 x 10^3 - gathering 1.8 x 10^{-3} - transmission	0.0021 (gathering and transmission lines)
Texas Railroad Commission[4]	Natural gas	0.00112 (fiscal 1981) 0.00108 (fiscal 1982) 0.0011 (fiscal 1982)
Production of Natural Gas Lower Mobile Bay Field, Alabama[5]	Natural gas	0.0019
Energy Resources Conservation Board, Alberta, Canada[6]	Sour gas Natural gas	0.00022 0.0041

1 The data are based on "reportable incidents" which are defined by DOT regulations as including incidents that: (1) resulted in death or injury requiring hospitalization; (2) required removal from service of any segment of transmission pipeline; (3) resulted in ignition; (4) caused $5,000 or more in damage; (5) involved a leak requiring immediate repair; or (6) in the operator's judgment, was significant even if the above criteria were not met.

2 David Jossi, Information Systems Division, Research and Special Programs Administration, U.S. DOT 1982.

3 LLNL, based on DOT data for 1970-80 (1984). Covers entire U.S. national gas transmission and distribution system.

4 Sonny Hollub, Texas Railroad Commission 1982.

5 Production of Natural Gas from the Lower Mobile Bay Field, Alabama, FEIS, U.S. Army Corps of Engineers, May 1982.

6 Wendy E. Roberts, Energy Resources Conservation Board, Calgary, Alberta, Canada 1982.

CASE STUDIES

Big Piney, Wyoming Blowout

A blowout occurred at a well operated by American Quasar in the Riley Ridge gas field near Big Piney, Wyoming on June 21, 1981. According to a report by Hanson (1981), estimates of the volume of gas released ranged from 5 to 100 million cubic feet per day, with a concentration of 3 to 4 percent hydrogen sulfide by volume, 70 percent carbon dioxide and 19 to 20 percent methane. The well was brought under control after 8 days. The closest residence was located 2 miles away. Ranchers were evacuated from the area except for short return visits to irrigate and feed cattle. No adverse human health effects were reported nor were any losses of or ill effects on cattle

reported. Four antelope and one moose were found dead between 0.3-0.5 mile away. There were also some dead jackrabbits and birds. The highest downwind readings taken at stationary monitors were 20 ppm about 2 miles away and 2 ppm 5 miles away. A mobile monitoring station measured concentrations generally ranging from 100-300 ppm at a distance of one mile. One reading of 6,500 ppm was also obtained (Environmental Research and Technology Inc. 1983b).

In its review of this well blowout, Layton et al. (1983) said that the situation would have posed a serious health hazard if the well had been located near homes. One noteworthy aspect of this blowout was that there was no fire. Because of the high percentage of carbon dioxide, the well would not burn without extra natural gas or butane being added. This would have complicated well control efforts if well ignition had been deemed necessary to reduce the hydrogen sulfide.

Lodgepole, Alberta Blowout

A well owned by Amoco Canada Petroleum Company located approximately 20 km west of Lodgepole, Alberta blew out of control on October 17, 1982 after reservoir fluids unexpectedly entered the well bore and created a kick. A formal ERCB inquiry into the circumstances of the blowout (1984) found that the kick was not controlled because (1) the crew did not immediately recognize the problem and immediately apply and maintain standard control procedures; (2) several pieces of vital equipment did not function properly; and (3) supplies of mixed drilling mud were not adequate during the kick-control operation.

The blowout was not controlled for 67 days. According to the ERCB, the main reasons were that the flow rate from the well was much higher than expected, weather conditions were frequently unfavorable, and safety procedures and equipment, while typical for the industry, were not adequate to cope with the magnitude and type of emissions from the well. The gas was estimated to be flowing at a rate of 1.4 million cubic meters per day or 49.4 million cubic feet per day, with an estimated hydrogen sulfide content of 25 percent. The highest hydrogen sulfide concentrations monitored in population centers during were 14 ppm in two small communities located about 20 km from the well, 3 to 5 ppm in a community of 5,000 persons located 45 km away, and 0.5 ppm in Edmonton, 130 km away. A concentration of 23 ppm occurred at a lumber company located about 10 km from the well site. These peak concentrations generally occurred for a few hours or less. There were six occasions when concentrations at local rural residences reached the established evacuation level of 15 ppm and people left the area. Two workers were killed during the blowout episode.

There were no scientific medical studies conducted during the period of the blowout, but based on testimony submitted by area residents and hospital patients in Edmonton, the ERCB Inquiry Panel concluded that the well emissions caused short-term health effects for a substantial number of people. Also, the panel found that some people, especially those with respiratory problems, were much more likely to suffer unfavorable effects. Health effects included headaches, eye irritation, and respiratory tract symptoms. As a result of this blowout and the subsequent Inquiry, the ERCB concluded that there was a need to re-examine safety procedures and policies concerning the drilling of sour gas wells to prevent future blowouts and to more effectively handle

emergency situations (see later section on review of current Alberta policies and regulations).

HEALTH RISK MODELS

Health risk assessment models also are often designed conservatively (using worst-case assumptions they may predict higher hydrogen sulfide concentrations over a larger geographic area than would actually occur). In order to identify a danger zone, it is necessary to estimate a hydrogen sulfide release rate. This rate is then used in an atmospheric dispersion model to determine a radius or downwind zone of exposure to certain concentrations of hydrogen sulfide. The release rate estimate is based on the expected or measured concentration of hydrogen sulfide in the gas stream plus the estimated flow rate under uncontrolled conditions. This estimate is easiest to obtain for production wells due to the availability of information about a particular formation derived from actual well test data. The uncertainty of the estimate is greatest for exploratory wells where data must be extrapolated from other wells drilled to similar depths and the same target formation. In some cases in Alberta these "analog" or reference wells may be located several hundred miles from a proposed wildcat well (Wiley 1988). Layton et al. (1983) recommends pooling data from sour gas wells located in different fields and completed into several formations if a wildcat well is being drilled into an area where subsurface geology is poorly defined.

Radius of Exposure Calculations

Lawrence Livermore National Laboratory (LLNL) calculated a worst-case scenario, assuming a surface level gas release occurs when atmospheric conditions are stable and wind speed is low. While acknowledging that a surface release would more likely be associated with a pipeline rupture (see next subsection) than a well blowout, LLNL calculated (using Gaussian diffusion models and Pasquill-Gifford stability classes) a worst-case surface release using data from wells in the western Wyoming Overthrust area for the estimated flow rate (Layton et al. 1983). LLNL established 300 ppm as the concentration at which acute health effects would occur and assumed "no effect" at less than 300 ppm for an averaging time of 10 minutes. Acute health effect was defined as unconsciousness, respiratory arrest, pulmonary edema or death. If a vertical, "momentum-dominated" gas release were to occur, LLNL's calculations indicated that there would be no acute health effects and therefore zero risk. For this case, LLNL determined that hydrogen sulfide concentrations of 300 ppm could occur 0.6 to 0.8 miles from the well. Also, ground-level concentrations could cause odor-related complaints and eye irritation at greater distances. For an elevated gas plume, where maximum concentrations would generally occur under unstable atmospheric conditions, a peak concentration of 35 ppm within a 500 meter radius of the well site was predicted.

LLNL calculated the probable risk of adverse health effects from a well blowout to equal the probability of accidental gas release during a certain time period times the sum of probabilities of the gas release occurring among a range of meteorological conditions.

Using a blowout probability factor based on the Alberta and Texas blowout frequency data, the risk of a surface release occurring and causing an

acute health effect over a 20-year period at a distance 1.5 km from the well was 0.000240 percent. By comparison, an individual's risk of accidental death due to a natural disaster over a 20-year period is 0.00014 percent (Layton et al. 1983).

Emergency Planning Regulations

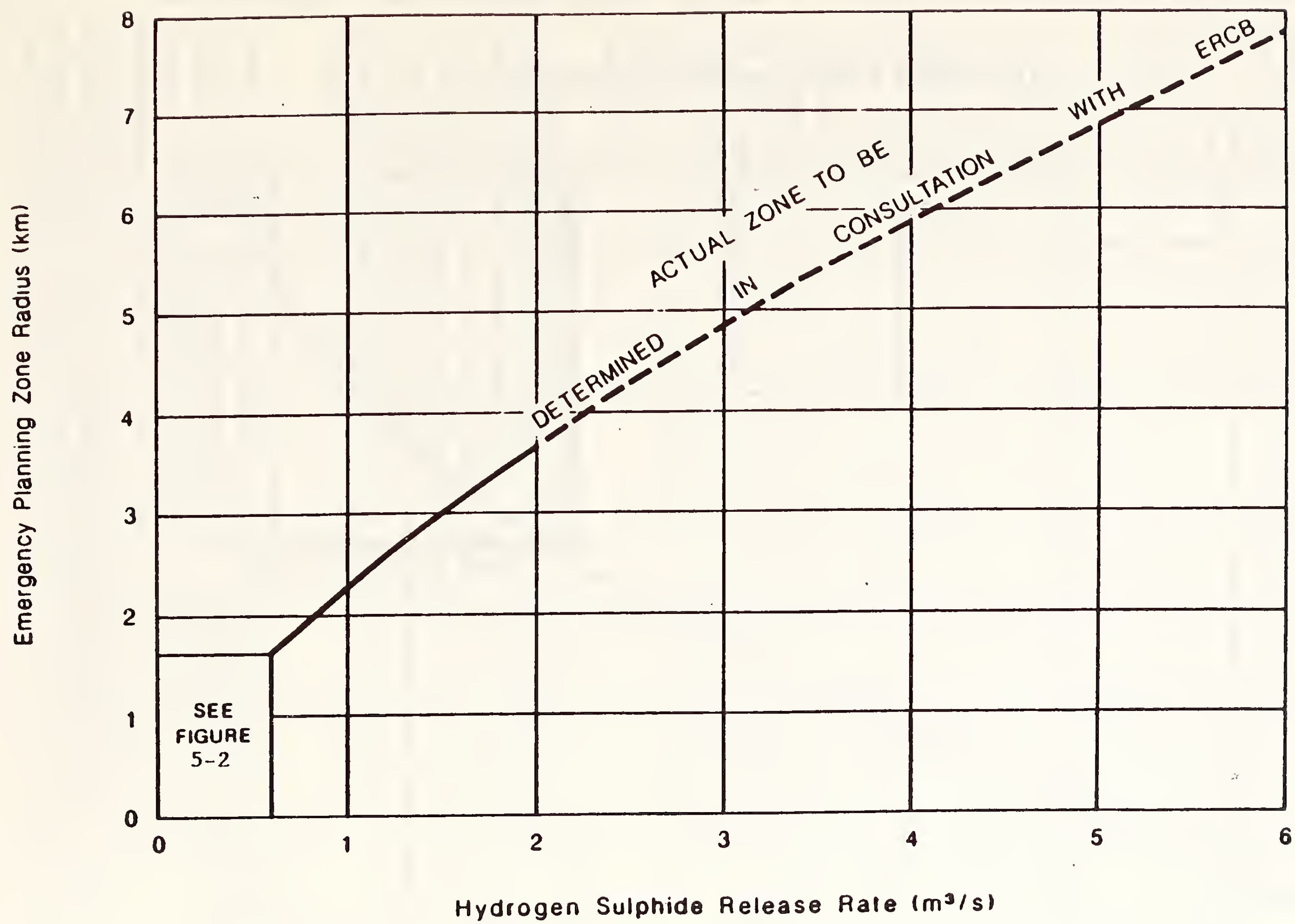
In its regulations, the Energy Resources Canada Board (ERCB) has published graphs that indicate the radius of the emergency planning zone (in kilometers) that should be used for wells with hydrogen sulfide release rates ranging from 0.01 to 2.0 m/s (see Figures 5-1 and 5-2). The zones range in size from an approximately 0.1 to 1.0 kilometer radius for wells that could release a maximum of 0.01 to 0.3 m/s of hydrogen sulfide and an approximately 3.7 km radius for a well producing 2.0 m/s. For wells with release rates higher than 2.0 m/s the zone is determined through consultation between the operator and the ERCB. The graph is based on worst case meteorological modeling and the predicted 100 ppm hydrogen sulfide isopleth. Operators have the option of collecting site-specific meteorological data and factoring in other information such as terrain characteristics in order to show that the worst case scenario reflected in the ERCB's graph is not applicable and that a smaller planning zone is adequate (Wiley 1988).

In an application to the ERCB to drill a well north of Waterton Lakes International Peace Park, Shell Canada identified two zones of importance for emergency response purposes. The emergency planning zone was the area around the well that would be evacuated in the event that control of the well became a concern. An emergency awareness zone arbitrarily defined the area within which Shell Canada planned to contact residents and others to inform them of the drilling and emergency plans. This zone included Waterton Park, residences east of the Waterton gas field, and areas northeast of the drilling camp. Under an assumed concentration of 32.7 percent hydrogen sulfide, and a release rate of 13.3 cubic meters per second, Shell's calculations indicated hydrogen sulfide concentrations could reach 100 parts per million about 1.4 miles downwind and 20 ppm at about 6.8 miles downwind (Energy Resources Conservation Board 1986).

Shell proposed to ignite the well if concentrations greater than 20 ppm were measured at the closest residence, or if company personnel were unable to search the emergency zone to ensure that transients were evacuated, or if the well could not be controlled in a short time. The ERCB ultimately approved drilling under the condition that the well would be immediately ignited if there was a total loss of control. The only permissible exception would be a small leak, if the Board was satisfied that public safety would not be threatened and that control was imminent.

Health Risks Associated With a Pipeline Rupture

While many of the parameters used to calculate health risks associated with well blowouts are also applicable to pipeline ruptures, there are important differences. Environmental Research and Technology Inc. (1983b) and Layton et al. (1983) evaluated risk assessment methodologies for calculating the potential health effects resulting from a pipeline rupture. The discussion is this section focuses on analyses for smaller diameter (approximately 6 inch) gathering lines because they are used in and around

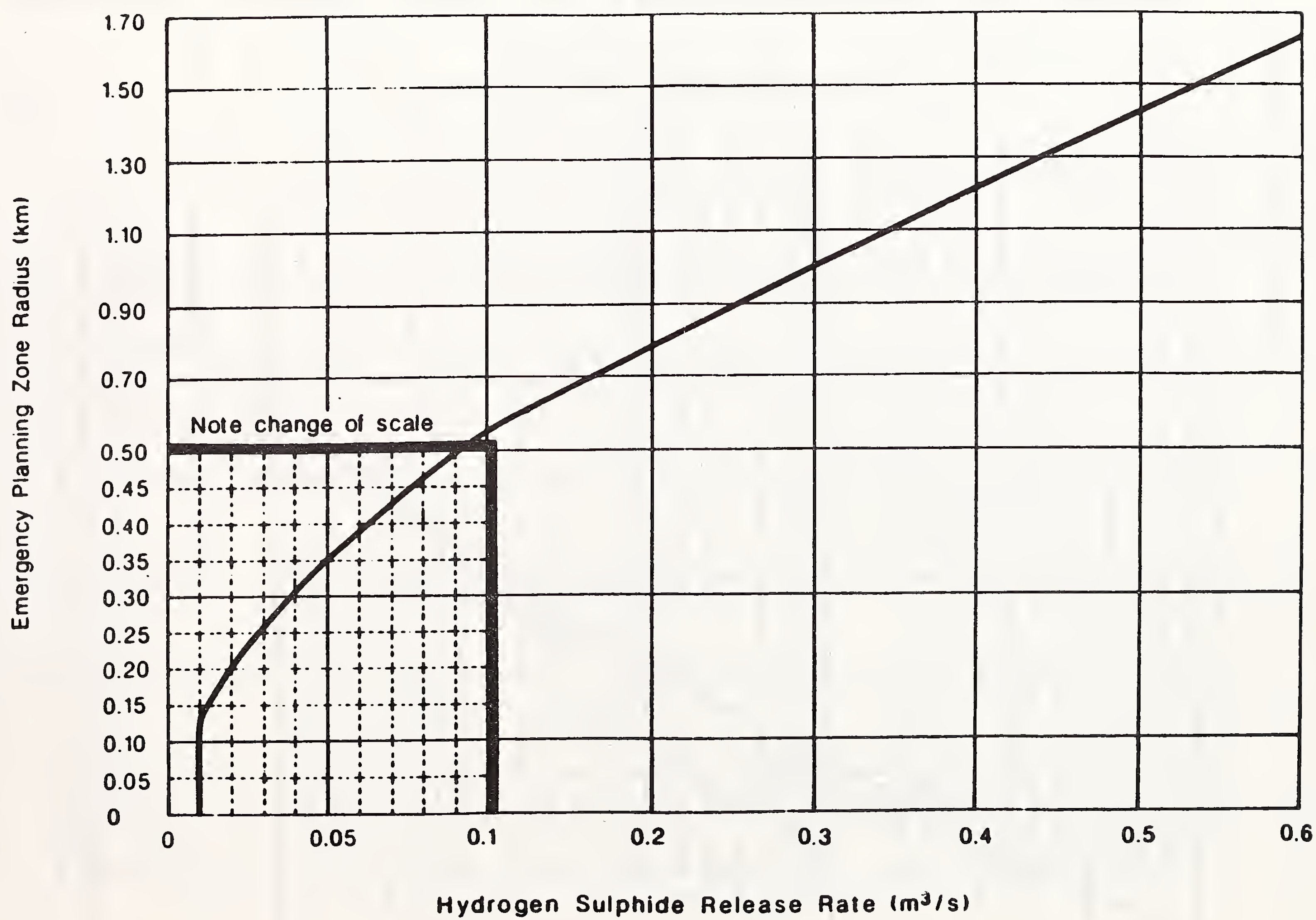


EMERGENCY PLANNING ZONE (1.8 TO 6 KM) GUIDELINES FOR SOUR WELLS

FIGURE 5-1

ID87-2

ERCB



EMERGENCY PLANNING ZONE (0 TO 1.7 KM) GUIDELINES FOR SOUR WELLS

FIGURE 5-2

ID87-2

ERCB

producing gas fields. Analyses of effects associated with large diameter pipelines are outside the scope of this document.

Most of the gas emitted from a pipeline rupture is typically discharged within a short time period. Environmental Research and Technology Inc. (ERT) reported that the discharge time would likely be less than 10 minutes and that the total dosage of any individual within about 10 kilometers of the rupture location would typically be experienced within less than 30 minutes from the time the rupture occurs. When a rupture occurs the gas initially escapes at high velocities in a transient cloud or puff. Block valves located upstream and downstream from the rupture would then close, leaving the remainder of the gas in the ruptured segment to escape at a steadily decreasing rate. The amount of gas released depends on the distance from the rupture to the block valves and the length of time required for the valves to close. Field experiments have demonstrated that the soil overlying a pipeline is blown away in the first one or two seconds after a rupture occurs (Environmental Research and Technology Inc. 1983b). The levels of hydrogen sulfide concentrations downwind from a rupture are most influenced by pipeline pressure and the level of hydrogen sulfide in the gas. ERT found that when block valves are more closely spaced, hydrogen sulfide concentrations would be lower and would decrease more rapidly with distance, especially during worst case meteorological conditions (stable, low wind speeds). The height of the gas plume is also important, with lower heights resulting in increased predicted concentrations. ERT's model results indicated that instantaneous concentrations near the pipe would approach or exceed lethal levels during any meterological conditions, but that 15-minute average concentrations would not be likely to exceed 100 ppm regardless of weather conditions (1983b). ERT did not report the probability of a gathering line rupture, but for major trunk lines associated with the Riley Ridge gas development, the analyses indicated about a 0.1 percent probability of one or more ruptures occurring over a year and a 0.1 percent probability that a person located slightly over two miles away from a trunk line would be exposed to hydrogen sulfide concentrations of 100 ppm.

Layton et al. (1983) evaluated a number of models used to estimate potential effects of transient releases of sour gas from pipelines and concluded that the models generally suffer from a lack of validation by tracer studies to measure how the gas actually is emitted and how it disperses. Some of the difficulties noted in estimating pipeline failure frequencies are the complexities of accounting for pipe age, diameter, type of use, length, depth of cover, corrosion controls, soil conditions, operating pressures, construction techniques, materials, and maintenance and inspection procedures.

Layton et al. tested an analysis procedure based on an instantaneous puff model to assist the Bureau of Land Management in calculating "hazard zones" around a pipeline used to gather gas from producing wells. The case analyzed included the following assumptions: pipeline 1 mile long, 4 inches interior diameter, with a line pressure of 1,200 psi, carrying gas with 15 percent concentration of hydrogen sulfide gas, having a molecular weight of 25, temperature of 105 degrees F, and compressibility factor of 0.8. Lawrence Livermore National Labs (LLNL) calculated concentrations of hydrogen sulfide estimated to occur at 500, 1000, 1500, and 2000 meters from the point of rupture under stable atmospheric conditions. Both a surface-level release and

a release 10 meters in height were analyzed. Standard deviations of concentrations were also factored into the calculation. LLNL found that the maximum downwind hydrogen sulfide concentration for a surface level release and no initial cloud dispersion would be 613 ppm at 500 meters. With an initial rise of 10 meters the concentration at 500 meters from the pipeline was predicted to be 566 ppm. The predicted concentrations decreased substantially as distance from the well increased. LLNL concluded that for this example the danger zone was about 500 meters downwind.

BLM PROPOSED REGULATIONS

Well Control Equipment

The BLM's proposed regulations establish minimum levels of performance expected from all operators drilling on federal and Indian lands (BLM 1986a). These performance levels are expressed as well control standards for equipment, casing and cementing, mud programs and drill stem testing, as well as special provisions for operations employing air or gas drilling processes. The proposed regulations also identify whether a violation of any particular requirement or portion of a requirement would be considered major or minor, the type of corrective action that would be necessary, and the period of time within which the correction would have to be made.

BLM specifies four parameters that are of primary importance in selection of appropriate blowout prevention (BOP) equipment for any particular well: known or anticipated pressures, geologic conditions, accepted engineering practice, and characteristics of the surface environment. The pressure rating for the equipment must exceed the anticipated surface pressure of the well, assuming no fluid except gas in the hole.

In its reports on BOP equipment (1984) and well control operations (1987b) the API presents detailed discussion of all the BOP system components included in the proposed BLM standards.

Proposed regulations identify four categories of equipment pressure ratings--2000, 3000, 5000, and 10,000-15,000 pounds per square inch (psi). The minimum standard blowout prevention equipment required to accommodate pressures up to 15,000 psi is as follows: rotating head (as conditions warrant); annular preventer; two pipe rams, blind ram; 3-inch choke line; two kill line valves and check valve; remote kill line, unobstructed and run to edge of substructure; manual and hydraulic choke line valves; three chokes, one remotely controlled; pressure gauge on choke manifold; upper and lower kelly cocks, with wrenches available; safety valves and subs to fit all strings of drill pipe; inside blowout preventer or float sub available; wear ring in casing head; all connections subjected to well pressure are flanged, welded, or clamped; and fill-up line above the uppermost preventer.

Wells with lower pressures may not require much of this equipment under the BLM's proposed regulations.

Minimum standards are also specified for the choke manifold system (including diagrams of acceptable configurations based on anticipated well pressure), pressure accumulator system capacity, pump capacity and power availability for closing the blowout preventers, locking devices, and remote

controls. A number of standards for equipment testing are specified, including the timing and frequency of the tests.

In its report on BOP equipment systems (1984), the American Petroleum Institute (API) identifies the same four system design parameters specified by the BLM and also recommends that the corrosivity, volume, toxicity and abrasiveness of fluids should be considered in designing the choke manifold system. The API also provides schematic diagrams to aid in appropriate system design for specified pressure levels.

BLM's proposed requirements for casing and cementing include minimum design parameters, certain assumptions regarding formation pressure and fracture gradients that must be applied to wildcat wells if better data are lacking, and standards concerning quality of the casing, installation techniques, testing and minimum compressive strength of the cement. The mud program standards primarily address testing and monitoring requirements to help ensure that any changes signaling possible well control problems are promptly detected. Where pressures of 5,000 psi or greater are anticipated, electronic/mechanical mud monitoring equipment, a trip tank, and a mud gas separator are required. There also are requirements concerning the location and design of flare systems, including provision of supplemental fuel for ignition and continuous flaring if noncombustible gas is vented.

Drill stem tests must be conducted during daylight hours, although there is a provision for continuing the tests at night if the rate of flow is stabilized and adequate lighting is available. Minimum standards are established for flowing drill stem tests, separation equipment, and engines that operate during the tests.

Hydrogen Sulfide Operations

Initial hydrogen sulfide training for employees and installation and testing of safety equipment must be completed before drilling reaches a depth of 500 feet above, or 3 days prior to penetrating, the first zone containing or expected to contain hydrogen sulfide, whichever comes first. Factors to be considered in site planning to maximize safety include the prevailing winds, surrounding terrain, and the rig configuration. It is most desirable to situate the drilling rig so prevailing winds blow across the site toward the reserve pit. The regulations state that where practical, two roads should be established at opposite ends of the site or as dictated by the prevailing winds and terrain in order to provide alternate escape routes in the event that an accidental gas release occurs.

The proposed regulations state that operators should follow the API's recommended practices for safe drilling of hydrogen sulfide wells in order to properly train the employees. Initial pre-drill training must include a review of the site-specific drilling operations plan and public protection plan requirements (when such a plan has been prepared). Once drilling has commenced, hydrogen sulfide and well control drills must be held weekly, with a record of the drills kept in the driller's log or other document. Two briefing areas must be designated for organizing personnel in the event an emergency occurs. In its recommendations the API covers all of these items and additionally emphasizes proper maintenance of safety equipment, the drill fluid treating plan and use of mechanical ventilation equipment.

The BLM proposes to adopt the American National Standards Institute's standard for a proper respiratory protection equipment program. The API also recommends adherence to this standard as well as NIOSH and OSHA standards. The placement of breathing apparatuses at the site and on the rig and measures personnel must take to ensure that the equipment will fit properly are also addressed. Other equipment that must be available includes devices for communication between persons wearing the breathing apparatuses, a flare gun and flares to ignite the well, and where practical, devices that permit communication between the rig and a safe area.

According to both the BLM's proposed regulations and API recommendations, hydrogen sulfide monitoring equipment must be capable of detecting threshold limits of 10 ppm and 20 ppm in the ambient air. Both visible and audible alarms and wind direction indicators must be installed at specified locations. Other provisions include the placement of danger signs to warn persons entering the well site. The BLM's proposed regulations specify that red flags must be posted if concentrations greater than 20 ppm are detected. At 20 ppm, non-essential personnel must be moved to a safe area and workers must wear the protective breathing apparatuses. By comparison, API recommends that caution signs be displayed at 20 ppm and a red flag be posed only under extreme danger conditions when 50 ppm is measured. Sulfur dioxide detection equipment capable of sensing an ambient concentration of 5 ppm must also be available. Under the BLM proposal, if 5 ppm occurs at any occupied residence, school, church, park, or place of business, public protection measures must be implemented (see following subsection).

A flare system is required to gather and burn hydrogen sulfide gas. The proposed BLM regulations specify that the flare must be located a minimum of 150 feet from the wellbore unless otherwise approved by the agency, but that the lines should be as far from the operation as feasible and located in a manner to compensate for changing winds. A remote controlled choke is required for all hydrogen sulfide drilling. If formation pressures are unknown, a mud-gas separator and rotating head must also be used. Also, a pH of 10 or greater must be maintained in water-based mud systems in order to control corrosion and prevent sulfide embrittlement, unless other conditions justify a lesser level. De-gassing of mud must be accomplished in accordance with API recommended procedures that address placement of the drill fluid line to the degasser and provisions to flare the gas that is removed. All equipment that could be exposed to hydrogen sulfide must have metallurgical properties chosen in consideration of both the working environment and anticipated stresses. These properties include the grade of steel, the manufacturing method, and resulting strength properties. The materials must conform to the National Association of Corrosion Engineers standard for sulfide stress cracking resistance. This consideration is one of the most important differences between equipment used on a sour gas versus a non-sour gas well.

Unless special approval is obtained, drill-stem testing of hydrogen sulfide zones may only be done during daylight hours and fluids may not be allowed to flow to the surface.

The BLM proposes special requirements for production storage tanks that accumulate vapor in excess of 500 ppm hydrogen sulfide in the tank. Entry to

stairs and ladders must be restricted and a permanent wind direction indicator must be installed. Also, a danger sign must be posted within 50 feet of the facility to warn the public. The facility is located within ?-mile of city limits or a place the public could be expected to frequent, fencing and a locked gate must be installed to keep people away. There are similar requirements for other production facilities such as the wellhead, flowlines, piping, treating or separating equipment, water disposal pits, and processing plants that contain hydrogen sulfide concentrations of 100 ppm or more.

If concentrations of 20 ppm are measured within 50 feet of a production facility, the operator is required to take measures to reduce vapors from the system. Also, modifications are required if a production facility vents or flares gas resulting in hydrogen sulfide concentrations of 20 ppm or sulfur dioxide concentrations of 5 ppm at an occupied residence or other areas the public could reasonably be expected to frequent.

Public Protection Plan

BLM proposes to require a public protection plan if drilling would occur where: the 100 ppm "radius of exposure" exceeds 50 feet and includes an occupied residence, school, church, park, school bus stop, place of business, or other areas the public could reasonably be expected to frequent; 2) the 500 ppm radius of exposure is greater than 50 feet and includes any part of a public road; or 3) the 100 ppm radius of exposure is 3000 feet or more and includes facilities or roads that are maintained for direct public access. The 100 ppm and 500 ppm radii of exposure for gas containing less than 10 percent hydrogen sulfide are determined according to equations specified in the proposed regulations and derived from the Pasquill-Gifford atmospheric stability model. For gas containing 10 percent or greater hydrogen sulfide, applicants must calculate the radius of exposure using a dispersion modeling technique that considers representative wind speed, direction, atmospheric stability, terrain, and other relevant features. If a well is proposed for an area where data are insufficient to calculate a radius of exposure, a radius of at least 3,000 feet must be assumed. A radius of 3,000 feet is equal to or larger than the radius for most wells where the Pasquill-Gifford equations are used. However, based on terrain characteristics and proximity of residences or other places the public may frequent, especially downwind from the drill site, the BLM may require a radius larger than 3000 feet (Kruger 1988b).

BLM regulations describe requirements for public protection plans to address or include the following items: (1) the responsibilities and duties of key personnel and instructions for alerting the public and requesting assistance; (2) a list of names and telephone numbers of residents within the radius of exposure and procedures defining how and when these persons would be notified if an emergency occurs, including procedures for notification before a gas release actually occurs; (3) a telephone call list for contacting law enforcement, fire, and medical officials, including the type of information that would be communicated and the type of response(s) that would be necessary; (4) a map showing private and public dwellings, schools, roads, recreational areas, and other areas where the public might reasonably be expected to be found within the 100 ppm or 3000 foot radius, as applicable; (5) information that would be provided to local residents in advance briefings, including hazards of hydrogen sulfide and sulfur dioxide, instructions for reporting a leak to the operator, how notification of an

emergency would occur, and subsequent steps such as evacuation of the public and safeguards against property loss; (6) guidelines for ignition of the gas that define when, how and by whom this action would be taken; (7) monitoring, site security and communication activities that would occur following a gas release; and (8) for production facilities, a description of hydrogen sulfide detection systems.

ENERGY RESOURCES CONSERVATION BOARD REGULATIONS

The minimum separation distances between a proposed well that could produce hydrogen sulfide and residential or other developments are shown in Table 5-4.

Table 5-4. Summary of Minimum Distance Requirements Separating Proposed Sour Wells from Residential and Other Developments.

Level Classification	Producing/Suspended H2S Release Rate m^3/s (section 4.3)	Minimum Distance from Proposed Well to Various Developments
1	>0.01 - <0.3 (0.032 - 0.97 lbs/sec) (14.6 - 438 g/sec)	0.1 km
2	>0.3 - <2.0 (0.97 - 6.43 lbs/sec) (438 - 2,921 g/sec)	0.1 km to any dwelling 0.5 km to any urban centre or public facility
3	>2.0 - <6.0 (6.43 - 19.3 lbs/sec) (2,921 - 8,762 g/sec)	0.1 km to any dwelling 0.5 km to an unrestricted country development 1.5 km to an urban centre or public facility
4	>6.0 (19.3 lbs/sec) (8,762 g/sec)	As specified by the ERCB but not less than Level 3

NOTE: Any well classified as a Level 1, 2, 3, or 4 sour well may also be classified as a critical sour well.
Source: ERCB, ID 87-2.

The provincial land use planning commission has passed regulations restricting new residential and other types of development from encroaching on oil and gas wells within the distances in the above table (Wylie 1988). Alberta has placed considerable emphasis on planning for sour gas development because about one-half of the gas produced in the province contains hydrogen sulfide and approximately three-quarters of the sour gas wells are located within 10 km of a city, town or village, mostly within an 80-km-wide corridor between Calgary and Edmonton (Concorde Scientific Corporation 1987).

Critical sour wells are defined according to their maximum hydrogen sulfide release rates and proximity to urban centers. Table 5-4 lists the hydrogen sulfide release rates and separation distance required. Of 4620 wells licensed during 1986 in Alberta, 42 were 42 critical sour wells. Thirty-one of these were considered critical because their potential hydrogen sulfide release rates were greater than 2.0 m/s. The other 11 were classified as critical because of their proximity to residences or other developments (ERCB 1987c).

Following recommendations resulting from its formal inquiry into the causes of the Lodgepole well blowout, the ERCB developed "Alberta Recommended Practices for Drilling Critical Sour Wells" (1987b) to guide operators. In its regulations, the ERCB agrees with the findings of the Lodgepole Blowout Prevention Review Committee that "...although strict legal enforcement of good practices is not desired or possible ...such practices place considerable onus on the legally responsible party to comply or otherwise provide a technically equivalent or better solution" (ERCB 1987a). Based on this policy, the ERCB's regulatory approach for critical sour wells is to require operators to submit a drilling plan describing the planning, drilling equipment and procedures it proposes to use. It should be noted that the decision on whether a well is to be treated as a critical sour well is made early in the drill application process, based on initial locational data and predicted hydrogen sulfide release rates submitted by applicants planning to drill into the designated hydrogen sulfide zones.

Items that must be addressed in the drilling plan for a critical sour well include the following: geological information; a summary of any problems or adverse drilling situations that have occurred in nearby wells and assessment of how such problems would be addressed if they occur at the proposed well; a description of the drilling equipment (see following discussion); a discussion of the drilling fluid system including type, density, quantity, hole volume, surface volume, stockpile supplies and availability, hydrogen sulfide scavenger, and mixing and pumping equipment; drilling procedures, including inspections and testing, employee training and drills, and procedures to ensure wellbore and casing integrity; a description of the monitoring that will be employed to ensure prompt detection of problems; and information concerning crew numbers and qualifications.

The ERCB also has established a number of minimum requirements, many of them similar to those in the proposed BLM regulations for the blowout prevention stack, choke manifold, mud-gas separators, rig inspections and record-keeping, kick detection, use and operational capability of trip tanks, hydrogen sulfide monitoring and detection, intermediate casing, and materials and quality control specifications for the drill pipe and drill string valves.

Some areas where the Alberta regulations differ from BLM's proposed requirements include an emphasis by ERCB on blind shear rams with operators required to assess the need for them. Detailed rig inspections are to be performed weekly by the operator. Also, the ERCB field staff must be notified in advance so they can witness the activities. Detailed specifications stipulate the sensitivity/capability and operation of the automated mud tank volume monitoring system and the trip tank. Hydrogen sulfide sensors capable of detecting 5 ppm and ambient air monitors that can

detect 10 ppm are required. The regulations also establish minimum levels of education and certification for on-site supervisors, rig managers and drillers, including the requirement that these persons and the mud-men, loggers, geologists, and all other operations personnel must have previous experience in sour well drilling.

If a well is classified as a critical sour well or if there are one or more dwellings, public facilities, work sites, places of business, or similar areas/structures within the emergency zone, the operator is required to prepare an emergency response plan. The shape of the zone must reflect local terrain and population density considerations. The ERCB accepts guidelines prepared by the Canadian Petroleum Association (1987) as meeting the minimum standards for emergency response plans, although the ERCB reserves the right to determine the level of detail that is necessary on a case-by-case basis.

MITIGATION - HEALTH AND SAFETY

Virtually all safety hazards associated with oil and gas drilling and production can be mitigated, and in many cases they can be avoided entirely, through proper use of equipment and implementation of safety measures. The discussion in this subsection reviews safety measures and equipment and criteria and processes used by industry and government agencies to determine what is appropriate for any particular well. Establishment of minimum standards of guidelines regarding well blowouts, drilling of wells likely to contain hydrogen sulfide, and public protection plans are the most likely prevention measures to be taken to reduce potential health and safety impacts that may result from an uncontrolled release of toxic gases into the atmosphere.

Hydrogen Sulfide Operations

BLM and Alberta are taking a comprehensive approach to matters of health and safety when drilling involves a hydrogen sulfide operation.

<u>BLM Proposed Regulations</u>:

BLM's proposed regulations concerning hydrogen sulfide (1987b) are intended to apply to all onshore federal and Indian oil and gas leases where drilling or completion, testing, reworking, production, injection, gathering, storing or treating operations are conducted. Sulfur dioxide that would be created as a result of flaring the hydrogen sulfide gas is also covered. The regulations would apply to geologic "zones" that are known or can reasonably be expected to produce gas containing 100 ppm or more of hydrogen sulfide. For most wells, the likelihood of encountering hydrogen sulfide is determined on the basis of results of drilling that has occurred in the same formation in similar fields within the same geologic basin.

The proposed regulations require drilling operators to file a hydrogen sulfide drilling operations plan and, if necessary, a public protection plan as part of the application for a permit to drill. An operations plan is not required for production facilities or for well completion and workover operations, but certain operating requirements are specified. The proposed regulations also provide that gas analysis tests must be conducted for wells and production facilities that produce hydrogen sulfide, and that the results

must be made available to BLM. At a minimum, the hydrogen sulfide drilling operations plan must include: (1) a statement of certification that all personnel shall receive proper training; (2) a well site diagram showing the rig orientation, prevailing wind direction, surrounding terrain and locations of various safety-related facilities and briefing areas; and (3) a complete description of hydrogen sulfide safety systems and their use.

The following topics are specifically addressed by the proposed regulations: (1) site planning, pre-drill training for employees, and equipment testing; (2) protective equipment for personnel; (3) hydrogen sulfide detection and monitoring equipment; (4) drilling procedures and equipment, including the mud system, metallurgical specifications for materials and well testing; and (5) production facility operations. BLM's proposed requirements for oil and gas operations involving hydrogen sulfide are described in greater detail in earlier sections of this Appendix.

Alberta Energy Resources Conservation Board Regulations:

Alberta's system for regulation of sour gas wells has four main components (ERCB 1987a and 1987b): (1) a classification system and map of known geological formations and suspected geographical zones where potential for encountering significant hydrogen sulfide concentrations will be present; (2) a requirement that operators proposing to drill in the hydrogen sulfide zones must estimate the maximum potential hydrogen sulfide release rate from the proposed well; (3) a sour well classification system with four levels based on the maximum potential hydrogen sulfide release rates and establishing minimum separation distances between a proposed well and any dwelling, urban center or public facility; and (4) designation of certain wells as "critical sour wells" which must comply with more detailed planning and safety requirements than other wells.

The major components of emergency plans in Alberta are similar to those specified in BLM's proposed regulations. A map showing the dwellings, other developments, roads and topographical features within the emergency zone must be submitted. The map must also show an area at least twice the size of the emergency zone and the public facilities, urban centers and evacuation routes in that area. The ERCB specifies agencies that must be given copies of the plan and also requires that a meeting between the operator, the ERCB and the other affected agencies must meet prior to drilling. Continuous mobile air quality monitoring is required for wells with a high hydrogen sulfide release rate, or if portions of an urban center are located in the emergency zone. The ERCB also emphasizes the need for public participation during preparation of the emergency plan.

Montana Board of Oil and Gas Conservation (BOGC)

BOGC's regulations for rotary drilling operations require the use of blowout prevention equipment that is in accordance with established practice in proven areas (BOGC 1984). In unproven areas, the drilling equipment must include a mastergate or its equivalent, an adequate blowout preventer, and choke and kill line(s) of the proper size and working pressures. All flowing oil wells must be equipped with chokes or other adequate control equipment to ensure safe operations during normal production practices. The BOGC does not have special requirements for drilling wells that may encounter hydrogen

sulfide. For any producing well where gas containing 20 ppm or more of hydrogen sulfide is vented, a workable igniter system must be installed and other steps taken as necessary to ensure that all of the gas is burned. The BOGC may grant variances of this requirement on a case-by-case basis depending on the potential for human exposure, relative isolation of the well location, restriction of access, gas volume, and thermal content.

Other States' Regulatory Requirements

The Wyoming Oil and Gas Conservation Commission has a regulation that specifies the type of blowout prevention equipment that must be installed where formation pressures are abnormal or unknown, including the type and number of rams required in the BOP stack, upper and lower kelly cocks, and pit level indicators and/or flow sensors with alarms (Wyoming Oil and Gas Conservation Commission 1987). The accumulator must be capable of maintaining sufficient pressure at all times to allow the hydraulic preventers and valves to operate with no outside pressure source. The Commission has published a map showing the areas where this requirement applies. The minimum blowout prevention equipment for other areas with normal pressure is also specified. There are additional requirements for equipment installation, pressure ratings, and testing. The operator must submit a schematic diagram of the blowout prevention and wellhead assembly with the application for a permit to drill. There are no special requirements for drilling in hydrogen sulfide formations except that the blowout prevention equipment must be suitable for use in such areas.

The regulations of the Utah Board of Oil, Gas and Mining regulations require that operators drilling wildcat wells must take all reasonably necessary precautions to keep the well under control and provide proper high pressure fittings and equipment (Utah Board of Oil, Gas and Mining 1987). In proven areas the equipment must be in accordance with established and approved practice. The regulations include specific pressure tests that must be made on all ram type blowout prevention and related equipment, including casing. Also, in addition to initial testing, the ram and annular type preventers must be checked for physical operation each trip and tested monthly after drilling begins. Records must be kept of the tests.

Utah has a special rule concerning operating practices when hydrogen sulfide concentrations in excess of 20 ppm may be present. A written contingency plan must be submitted as part of the drill permit application, describing the actions that would be taken to protect workers and the public if a gas release occurs. The drill site must be planned to maximize safety benefits. The regulations also include specific requirements for worker protection equipment and communication devices, hydrogen sulfide detection and monitoring, warning signs, ventilation, the flare system, and hydrogen sulfide scavengers for the mud system.

TECHNICAL APPENDIX 6
WILDLIFE AND FISHERIES

EXISTING CONDITIONS

Elk

Elk, the favorite game and viewing species of many people, occur over 28 percent of the state at elevations from approximately 3,000 to 9,000 feet. Habitat includes forested, moist mountain environments and the arid Missouri River breaks.

Over most of their range, elk are critically dependent upon winter range, lower elevation grasslands, shrublands, and open forests. Migration routes link winter ranges with higher elevation summer and fall habitats. Calving requires specific types of habitat that provide the required security, weather conditions, and forage for maximum survival of both calves and cows. Security from both predators and hunting is an important habitat feature.

Mule Deer

Mule deer range over 90 percent of the state at a wide range of elevations. During the winter, mule deer use low elevation ranges with woody browse plants. In eastern Montana, coulees, draws, and riparian habitats are extremely important in winter for shelter and food. During the summer, these areas are important because the vegetation remains succulent and productive during dry periods while adjacent grasslands dry out.

White-tailed Deer

White-tailed deer range over 33 percent of the state in brushy cover along rivers and streams, ponderosa pine forests in eastern Montana, and in closed canopy forests of Douglas fir and ponderosa pine west of the Continental Divide. Whitetails have adapted and flourished where croplands are interspersed with suitable escape and security cover. As with elk and mule deer, suitable winter range is critical for survival and reproduction of whitetails.

Antelope

Antelope inhabit 47 percent of the state, primarily east of the Continental Divide, in open and rolling sagebrush and grassland plant communities. Antelope use sagebrush as their primary winter food and consume other native plants and agricultural crops during the other seasons. During harsh winters, antelope typically migrate to areas with suitable browse and less snow.

Moose

Moose inhabit approximately 18 percent of Montana, primarily in the western part of the state, in conifer and deciduous forest communities, and often close to water. Moose forage seasonally on both browse and forbs, but willow is preferred during the winter.

Bighorn Sheep

Bighorn sheep occur in 3 percent of the state. Their habitat requirements include open slopes near escape cover, such as cliffs, rocky ledges, and steep rocky slopes. Bighorns use the same breeding areas, salt licks, and migration routes year after year and do not easily adapt to changes in habitat.

Bighorns normally stay in herds and are susceptible to disease. They are vulnerable to competition from domestic livestock and native animals. They exhibit complex stress and disease interactions which render them especially sensitive to environmental changes.

The largest herd of bighorn sheep in the contiguous United States is the Sun River herd along the Rocky Mountain Front. This herd has increased from an estimated 260 head in 1943 to approximately 1,000 head in 1983 (Interagency Rocky Mountain Front Wildlife Monitoring/Evaluation Program 1987).

Mountain Goats

Mountain goats occur in 4 percent of the state in isolated, rugged mountains at elevations over 5,000 feet. Goats tend to use higher elevations during the summer and to move lower in the winter. In some areas, goats move in winter to higher elevations where the wind has exposed forage on the upper slopes. Typically, goat winter ranges are small and sparsely vegetated with limited carrying capacities.

An important feature of mountain goat behavior is their strong desire for salt. Mountain goats will use salt licks during all months of the year to relieve a sodium imbalance related to their seasonal shifts in food habits (Herbert and Cowan 1971). The goats' desire for salt can lead them into insecure habitat away from escape terrain where they are vulnerable to predation (Interagency Rocky Mountain Front Wildlife Monitoring/Evaluation Program 1987).

Black Bear

Most black bear in Montana are found in the northwestern part of the state, but they are fairly numerous as far east as the Absaroka Range and the foothills along the Rocky Mountain front. Although black bears can become habituated to human developments, they thrive best where their habitat has not been altered.

Black bears eat a wide variety of both plant and animal foods. They select succulent green forage in the spring after leaving their dens. South-facing open slopes, road margins, and riparian areas are heavily used in the spring. Black bears are most vulnerable to environmental disturbance during the winter when they are in their dens.

Grizzly Bear

The grizzly bear is restricted to mountainous terrain in northwestern Montana and in south central Montana adjacent to Yellowstone Park. The highest population densities of the grizzly in Montana occurs in Glacier National Park and in the mountain ranges that extend southward from the Park.

According to Dood et al. (1986), grizzly bear densities varied from 1 bear per 6 square miles in the North Fork of the Flathead River to 1 bear per 19 square miles in the Mission Mountains. On the Rocky Mountain front, the average grizzly density between 1980 and 1986 was 1 bear per 20 square miles. In the Cabinet-Yaak ecosystem in northwestern Montana, the density of grizzlies is approximately 1 bear per 100 square miles.

Aderhold (1988) reports that the Cabinet Mountain-Yaak River grizzly bear ecosystem comprises approximately 1 million acres and supports 25 to 50 grizzly bears. The Glacier Park-Northern Continental Divide ecosystem encompasses about 6 million acres and has an estimated 500 to 800 bears. The Yellowstone grizzly population inhabits portions of the Gallatin and Beaverhead national forests and has an estimated 200 to 300 animals. The northern Continental Divide grizzly population is stable and may be increasing; the Cabinet Mountain population is believed to be decreasing; and the Yellowstone population appears to be slightly increasing. In total, the grizzly population in Montana is estimated to be between 600 and 900 animals.

In the past, the range of the grizzly bear included the plains of eastern Montana. The grizzly in Montana still use the grasslands, riparian areas, and foothills along the Front Range. The Front Range is the only area in the United States where the grizzly's established pattern of use includes both mountains and plains.

Important grizzly bear habitat includes seasonal use-areas such as those for spring forage and fall-winter denning areas, and travel corridors between seasonal or alternative feeding areas (Interagency Rocky Mountain Front Evaluation Program 1987).

Black-footed Ferret

The endangered black-footed ferret once was resident in large prairie dog colonies east of the Continental Divide. The ferret depends almost entirely upon the prairie dog for food and shelter and the decline in ferret numbers has been linked to the near eradication of prairie dogs.

There have been no verified black-footed ferret sightings in Montana since 1979, when a ferret was seen in Carter County near Ekalaka (Aderhold 1988). It is not known whether any black-footed ferrets exist in Montana, but they are most likely to be found in Phillips County or on the Charles M. Russell National Wildlife Refuge where extensive prairie dog colonies remain.

Gray Wolf

The only area in Montana known to be inhabited by the endangered gray wolf is in and around Glacier National Park. In 1986, a pair of wolves near Polebridge in Glacier National Park produced a litter of 5, the first known

wolf production in Montana in more than 50 years. In 1987, another pair produced a litter of six in the park. The reproduction of wolves in the park combined with migration to Montana from Canada has increased the state's wolf population to more than 30 animals.

Waterfowl and Shore Birds

Ducks, geese, and shore birds breed and migrate in all parts of Montana. Lakes and rivers are important breeding and nesting habitats in western Montana, whereas potholes and wetlands are critical habitat in eastern Montana. The best natural waterfowl breeding areas are the glaciated pothole areas in the Flathead Valley and around Glasgow. Loss of breeding habitat is the major threat to waterfowl populations.

The endangered whooping crane migrates through Montana and over the last 28 years there have been nearly 200 crane observations in the state. Two-thirds of the whooping crane observations have been on or within 20 miles of Medicine Lake National Wildlife Refuge in extreme northeastern Montana. A few whooping cranes have been observed at Red Rock Lakes National Wildlife Refuge in the Centennial Valley of southwestern Montana (Aderhold 1988).

The piping plover is a threatened species of shore bird that summers at the Medicine Lake National Wildlife Refuge and associated wetlands in Sheridan County, at Nelson Reservoir near Malta, and at the east end of the Fort Peck Lake. In 1987, 74 adult plovers and 19 nests were observed in pebbly, sandy areas along major water courses and on scoured sandbars with little vegetation. The decline in piping plover populations in Montana has been attributed to losses in habitat due to water and shoreline development, recreational use, predation by domestic pets and wildlife, reservoir inundation, stream channelization, and stabilization of shorelines and sandbars (Aderhold 1988).

In 1987, a pair of the endangered least tern was observed nesting on an island at the east end of Fort Peck Lake. Eastern Montana is the western most edge of the tern's range. The least tern feeds on small fish and crustaceans and nests on sandbars near shallow water feeding areas with good minnow populations (Aderhold 1988). The decline in populations in the least tern has been attributed to losses in nesting and feeding habitat due to artificial regulation of rivers and man-made changes in river hydrology.

Prairie Grouse

Sharp-tailed and sage grouse are native species occupying the grassland-sagebrush habitats of Montana, generally east of the Continental Divide. Both species return each spring to customary courtship areas called leks or strutting grounds where they breed. The same strutting grounds are used year after year even if roads or other developments intrude. Nesting occurs in suitable habitat within 2 miles of the strutting grounds.

Sage grouse depend on sage, their sole dietary component during the winter, and eat other greens and insects during the spring, summer, and fall. Wintering areas are critical habitat for sage grouse and are often located on large, flat expanses of sagebrush tall enough to be partially exposed above the snow. During mild winters, sage grouse are widely dispersed. As snow

depth increases, grouse populations concentrate in smaller areas where sagebrush remains exposed (Barry 1988).

Sharptails rely primarily on insects, seeds, and fruits and will feed on grain if it is available. Sharptails winter in coulees where shrubs and deciduous trees provide food and cover.

Birds of Prey

Various birds of prey (raptors), including hawks, owls, falcons, eagles, osprey, and vultures, are found throughout the state. Although some of these birds congregate at certain times of the year, such as during migration or where prey is abundant, they usually occur singly or in pairs.

Cliffs and riparian habitat are the two most important nesting habitats for raptors. Along the Rocky Mountain front, cliffs provide nesting habitat for all of the prairie falcons, 87 percent of the golden eagles, and a small percentage of red-tailed hawks, ferruginous hawks, and great horned owls. Riparian habitat along the Rocky Mountain front comprises only 5.4 percent of the land in the state, but provides nesting habitat for 96 percent of the Swainson's hawks, 93 percent of the red-tailed hawks, 60 percent of the great horned owls, and 4 percent of the golden eagles (Interagency Rocky Mountain Front Wildlife Monitoring/Evaluation Program 1987).

The endangered bald eagle winters statewide with the highest concentrations occurring along rivers where fish and waterfowl provide an adequate prey base. The bald eagle nests in all areas of Montana except the northeastern one-fourth of the state. In 1987, 60 occupied nests were found in Montana with more than 80 percent of the nests in the western part of the state. Populations of the bald eagle in Montana appear to be slowly increasing, but the bird is threatened by loss of habitat and by human disturbance.

The endangered peregrine falcon migrates throughout Montana, but nests only in the Gallatin and Centennial valleys where it has been reintroduced into habitat previously used by this species. Since 1984, at least six pairs of peregrines have successfully nested and produced young (Aderhold 1988). The experimental reintroduction of peregrines into southwestern Montana has been successful and reintroduction will be attempted in other portions of the state.

WILDLIFE HABITAT IN OIL AND GAS DEVELOPMENT REGIONS

Western Region (Overthrust)

The Western Region of oil and gas development comprises about 32 percent of the state and is characterized by mountainous terrain dissected by river valleys. The major rivers in this region include the Clark Fork, Blackfoot, Bitterroot, Flathead, Beaverhead, Madison, Jefferson, Missouri, Yellowstone, and Big Hole rivers. Table 6-1 lists the miles of rivers and streams draining this region and Table 6-2 lists the length of each class of stream per square mile for each oil and gas development region. The Western Region supports all of the bull trout and westslope and Yellowstone cutthroat spawning areas in

the state. It also supports populations of stream-dwelling grayling, shorthead sculpin, and white sturgeon.

Table 6-1. Miles of Class I, II, and III Streams for Oil and Gas Development Regions in Montana.

	Classification of Streams		
Region	Class I	Class II	Class III
Overthrust	1,028 miles	1,078 miles	2,976 miles
Northern	473 miles	581 miles	1,187 miles
Williston Basin	256 miles	87 miles	317 miles
Central	25 miles	68 miles	417 miles
Big Horn	58 miles	72 miles	340 miles
Powder River	52 miles	90 miles	522 miles

Table 6-2. Length (feet) of Class I, II, and III Streams per Square Mile for Oil and Gas Development Regions in Montana

	Classification of Streams		
Region	Class I	Class II	Class III
Overthrust	115 ft/sq mi	121 ft/sq mi	334 ft/sq mi
Northern	71 ft/sq mi	86 ft/sq mi	177 ft/sq mi
Williston Basin	76 ft/sq mi	26 ft/sq mi	94 ft/sq mi
Central	6 ft/sq mi	15 ft/sq mi	93 ft/sq mi
Big Horn	23 ft/sq mi	28 ft/sq mi	136 ft/sq mi
Powder River	26 ft/sq mi	46 ft/sq mi	268 ft/sq mi

Red Rock Lakes National Wildlife Refuge is a breeding area for the trumpeter swan and other waterfowl and shore birds. The endangered whooping crane has been observed at Red Rock Lakes during migration. Ninepipe National Wildlife Refuge and Pablo National Wildlife Refuge in the Flathead valley and Lee Metcalf National Wildlife Refuge in the Bitterroot valley attract larger migratory populations of waterfowl and are also waterfowl production areas.

Most of the nesting bald eagles, peregrine falcons, gray wolves, elk, moose, mountain goat, mountain sheep, black bear, and grizzly bear in the state are in this region. Most antelope are east of the Continental Divide in sagebrush/grassland habitats. Sage grouse occur in the Shields River valley near Livingston and in the Big Hole and Beaverhead drainages. Most sharp-tailed grouse are along the Rocky Mountain Front and along the Madison River and upper Missouri River. Small populations of sharptails occur west of the Continental Divide near Helmville and in the Blackfoot River valley. Table 6-3 lists the acreage of winter range for five selected species in the various regions and Table 6-4 lists the acreage of winter range per square mile for each region. Winter ranges in the mountainous part of western Montana occur at lower elevations in foothills and valleys adjacent to summer and fall habitats. Winter ranges typically are linked to summer and fall

habitat by migration routes that are followed year after year. Winter range is the most important seasonal habitat because it is limited in area and has been eliminated or reduced by competing land uses such as residential subdivisions and livestock grazing. Animals on winter range are particularly susceptible to impacts because:

1) They are concentrated on limited areas.
2) During the winter, animals are usually under stress due to cold, limited forage, and because females are pregnant.

Table 6-3. Acreage of Winter Range for Oil and Gas Development Regions (Thousands of Acres)

Region	Mule Deer	Elk	Bighorn Sheep	Mountain Goat	Antelope	Total
Overthrust	4,169.8	3,115.7	121.3	413.2	641.5	8,451.5
Northern	4,627.7	703.9	8.1	46.9	1,058.0	6,444.6
Williston Basin	1,544.9	--	--	--	704/1	2,249.0
Central	2,057.4	91.7	--	--	2,649.9	4,799.0
Big Horn	830.0	92.9	59.9	27.8	131.8	1,142.4
Powder River	1,455.2	--	--	--	511.7	1,966.9

Table 6-4. Acres of Winter Range per Square Mile for Oil and Gas Development Regions.

Region	Mule Deer	Elk	Bighorn Sheep	Mountain Goat	Antelope	Total
Overthrust	88.5	66.2	2.3	8.8	13.6	179.7
Northern	131.0	19.9	0.2	1.3	30.0	182.4
Williston Basin	87.5	----	---	---	39.9	127.3
Central	87.3	3.9	---	---	112.6	203.8
Big Horn	62.7	0.7	4.5	2.1	10.0	80.0
Powder River	141.3	----	---	---	49.7	191.0

Northern Region (Sweetgrass Arch - Bearpaw Uplift)

The Northern Region of oil and gas development comprises approximately 24 percent of the state. The native vegetation of this region is primarily grasslands and sagebrush/grasslands with coniferous forests on isolated mountain ranges, including the Little Rockies, Bearpaws, Highwoods, and Sweet Grass Hills. The westernmost portion of this region includes the eastern part of Glacier National Park and the northern Rocky Mountain front. The northern Rocky Mountain front supports an abundance of wildlife. About 3,000 elk, 8,000 mule deer, 1,000 bighorn sheep, 250 mountain goats, 90 grizzly bear, and 300 black bear inhabit foothill and montane habitats of the front (Lindler 1988).

Freezeout Lake Wildlife Management Area, Benton Lake National Wildlife Refuge, and Bowdoin National Wildlife Refuge are breeding areas for ducks, geese, and other waterfowl. Lake Bowdoin has a nesting colony of white pelicans and many sandhill cranes visit the area during migration.

The portion of the Missouri River in the southern part of this region is designated a National Wild and Scenic River. Floaters and anglers use this reach of the river in large numbers during the summer. Fort Peck Reservoir is a popular recreation area and provides breeding habitat for the rare piping plover and least tern.

The Northern Region is an important agricultural area. The interspersion of grain and hayfields with native shrub, grassland, and riparian plant communities provides excellent habitat for white-tailed deer, pheasants, Hungarian partridge, sharptails, and antelope. Mule deer are abundant in the breaks, badlands, and hilly topography throughout the region. Sage grouse are found wherever there is extensive acreage of big sagebrush. Areas north of Fort Peck Lake have some of the biggest prairie dog colonies in Montana. These areas are probably among the best black-footed ferret habitat in the state due to the high population of prairie dogs, and may have ferrets present if the species is not yet extinct in Montana.

The major rivers in the Northern Region are the Missouri, Milk, Marias, and Teton. These streams are inhabited by walleye, northern pike, channel catfish, and other species adapted to cool and warm waters. The Missouri River supports one of only six self-sustaining populations of paddlefish in the United States. Paddlefish migrate as far as 145 miles upstream from Fort Peck Lake to spawn (Berg 1981). Ten critical spawning areas have been identified between Fort Peck Lake and the Three Islands area. Sauger, walleye, channel catfish, shovelnose sturgeon, blue suckers, smallmouth buffalo, bigmouth buffalo, and northern pike also migrate during spawning in the Missouri and Marias rivers (Berg 1981). The Teton River has a population of sturgeon chub.

Central Region (Big Snowy Uplift)

The Central Region comprises approximately 16 percent of the state. Big sagebrush/grassland habitat dominate in the eastern half of the region with native grassland and cropland dominant in the western half. The westernmost part of the region includes the southern extension of the Little Belt and Castle mountains, which contain productive elk and mule deer areas. The Big Snowy Mountains support populations of mule deer, elk, and wild turkey. The Bull Mountains near Roundup provide excellent habitat for mule deer and wild turkey.

Lake Mason National Wildlife Refuge and War Horse National Wildlife Refuge are important waterfowl breeding and nesting areas. The Charles M. Russell National Wildlife Refuge supports large populations of mule deer, antelope, elk, sharp-tailed grouse, and sage grouse.

In the western half of the region, salmonid species are the most numerous fish, with cool- and warm-water species more common in the eastern part. The Smith River and upper reaches of the Judith and Musselshell rivers are productive fisheries for rainbow and brown trout. The lower reaches of

these latter two rivers are inhabited by channel catfish, sauger, and other warm-water species which migrate upstream out of the Fort Peck Lake to spawn.

South Central Region (Big Horn Basin)

The Big Horn Basin comprises about 9 percent of the state. The region includes the highest mountain ranges (Absaroka and Beartooth ranges) and the most arid habitats in the state, including Big Horn Canyon and the Pryor Mountains. The montane habitats support grizzly bear, bighorn sheep, mountain goat, mule deer, elk, and black bear, whereas the most arid regions provide habitat for mule deer and chukar partridge. The river drainages and associated irrigated croplands are some of the best pheasant habitat in the state.

The major rivers are the Big Horn, Yellowstone, Clark Fork of the Yellowstone, and Rock Creek. The Big Horn and upper Yellowstone are productive brown trout fisheries. The Big Horn Canyon National Recreation Area is a popular boating and fishing area. Walleye are the most sought-after species.

Table 6-1 lists the drainage distances for rivers and streams in the region. Table 6-3 lists the acreage of winter range in the South Central Region.

Northeastern Region (Williston Basin)

The Northeastern Oil and Gas Development Region, comprising 12 percent of the state, is dominated by prairie vegetation interspersed with croplands, primarily small grains). Deciduous shrub and tree habitats form important wildlife habitat in the riparian areas and in upland coulees. The major drainages in the region are the Poplar River, Big Muddy Creek, Missouri River, and the lower Yellowstone River. Medicine Lake National Wildlife Refuge, an important breeding and nesting area for waterfowl, is used periodically by migrating whooping cranes.

Table 6-1 lists the miles of rivers and streams in this region and Table 6-3 lists the acreage of winter range. Almost all the fish in this region are warm-water species. According to Peterman and Haddix (1975), the lower Yellowstone supports 46 fish species. The most important sport-fishing species are walleye, sauger, and paddlefish.

Southeastern Region (Powder River Basin)

The Powder River Basin comprises approximately 7 percent of the state's area. The topography of this region is predominantly big sagebrush-dominated river breaks with the higher elevations such as the Custer National Forest supporting ponderosa pine habitats. The interspersion of ponderosa pine forest, sagebrush, upland deciduous, and riparian ecosystems provides rich habitat diversity with high wildlife values. Mule deer, white-tailed deer, antelope, sharp-tailed grouse, sage grouse, pheasant, and wild turkey are all numerous in this region. The Powder and Tongue rivers are the major streams although the Little Missouri and Missouri rivers also traverse portions of this region.

The Tongue River is a highly productive stream with smallmouth bass, northern pike, and channel catfish being the most numerous game fish. The Tongue River also has paddlefish and the only population of rock bass in the state. The Powder River is a naturally turbid river with high levels of dissolved solids and suspended sediments. Although the Powder River is not heavily used by fishermen, it provides habitat for the sturgeon chub, a species of special concern in Montana.

Table 6-1 lists the drainage area distances of rivers and streams in the region. Table 6-3 lists the winter range acreage for 5 selected wildlife species.

IMPACTS TO TERRESTRIAL ECOSYSTEMS

Studies of interactions of wildlife with petroleum development in Montana have focused on seismic exploration effects (Joslin 1986, Andryk 1985, Olson 1981, Interagency Rocky Mountain Front Wildlife Monitoring/Evaluation Program 1987) and have presented only limited data on effects of oil and gas wells and roads (Ihsle-Pac 1985, Aune and Stivers 1983). Because data specific to biological impacts of petroleum development in Montana are scarce, studies from other states and Canada have been reviewed. These studies include specific references to oil and gas development and to impacts of logging, hunting, road construction, and recreational activity. Any activities that alter habitat, disturb wildlife, obstruct wildlife movement, or cause direct or indirect mortality are relevant to interpreting the potential impacts of oil and gas development on wildlife in Montana.

Study findings by PRISM (1982) include the following:

1) Gregarious species are more severely affected by disturbance than are solitary species. In general, a herd of elk will run further than a moose will from the same disturbance.

2) Previously hunted individuals of a species will exhibit greater avoidance to disturbance (particularly road related) than will unhunted animals.

3) Species will habituate to a stationary disturbance such as a drilling rig much more readily than to moving disturbances such as traffic and people on foot.

4) The more predictable a disturbance, the more readily the animals become accustomed to it, and the less the potential for displacing animals.

5) Migratory or nomadic species tend to be more severely affected by a disturbance than resident species.

6) Habitat alterations generally have more serious impacts on winter ranges than on summer ranges.

7) The magnitude of impacts is related to the time of year during which a disturbance takes place, and could be more severe, for example, when females have young, or when bears are hibernating.

8) Females accompanied by young are generally more sensitive to disturbance than are adult males.

9) Mortality in species with low populations have greater biological consequences.

10) Species whose habitats include open areas such as alpine regions and prairie tend to be more severely affected by disturbance than forest-dwelling species.

The following discussion focuses on specific impacts of various aspects of oil and gas development on species of wildlife in Montana.

Access Roads

The most serious impacts to wildlife from hydrocarbon exploration and development would be caused by the construction and use of new roads (Schallenberger and Jonkel 1980). It has been well documented (PRISM 1982) that road-related kills, both legal and illegal, have reduced big game populations and increased the remaining animals' wariness and road avoidance. According to the Washington Department of Game and Fish (1980), the avoidance of roads may force animals into less desirable winter range. Besides losses in habitat, more roads lead to more harassment of wildlife and more road kills (U.S. Forest Service 1980).

Big Horn Sheep:

MacArthur et al. (1979) and MacArthur et al. (1982) reported that heart rates, an indicator of physiological stress, increased when bighorn sheep were near roads that had traffic and human activity. McKenna and Lynott (1980) found that oil and gas development in North Dakota, with a density of well development (and associated roads) ranging from one well per section to one well per quarter section, reduced the carrying capacity of the range for bighorn sheep. They attributed the loss in carrying capacity to reduced fecundity and increased disease due to stress caused by oil and gas development.

PRISM (1982) cited Dall sheep studies in Alaska which showed that sheep, habituated to humans in Mt. McKinley National Park, did not abandon large portions of range due to human traffic and other activity along roads. Road construction, in conjunction of the Trans-Alaska Pipeline, within 1.6 kilometers of a major Dall sheep wintering and lambing area did not cause range abandonment or reductions in lamb production. These studies substantiate the additional research findings of MacArthur et al. (1979) that bighorn sheep possess learning and adaptive capabilities and become habituated to humans in the absence of hunting. This adaptability is related to both stress and habitation factors described in following sections.

Grizzly Bear:

McLellan and Mace (1985) studied grizzly bear in British Columbia adjacent to Montana and found that grizzly habitat within 100 yards of roads was used less than more remote areas, and bears in remote areas were found to be more sensitive to disturbance than bears habituated to humans. Data from their study show that the majority of bear deaths due to shooting occur near roads.

Grizzly bear responses to oil and gas, seismic and other exploration activity along the Rocky Mountain front in Montana have been studied by Aune and Stivers (1983). They found that increased traffic and the development of new roads may significantly reduce available habitat. Data show that a road within 1,000 yards makes habitat less desirable to bears. Aune and Stivers

(1983) found that grizzlies also stay at least .5 mile away from drilling activity, and that shy bears may be displaced from much larger areas.

The effects of hydrocarbon development on grizzly bears remain poorly understood because long-term responses have not been studied (Peck et al. 1987). These researchers did, however, conclude that the greatest bear-related impact from oil and gas development in Montana results from road construction and use.

Black Bear:

There is not much information about the effects of oil and gas development on black bear. Aune and Stivers (1983) found that development of wells and roads on a female black bear's home range had little effect upon the bear or her cubs. A radio-collared bear was located several times within 500 yards of a drill site and denned within 100 yards of a road to a drill site. The bear and her cubs were not disturbed while hibernating, although a large backhoe operated within 100 yards of the den.

Tietje and Ruff (1980) studied black bear in Alberta at an oil development site and found that only one of the 17 bears studied curtailed habitat use due to oil development activities. They concluded, however, that increased roads and habituation of bears to humans may have a greater impact than habitat alteration due to legal and illegal shooting that invariably results when bears and humans interact.

Mountain Goat:

Chadwick (1973) documented short-term displacement of mountain goats in areas where road construction and blasting were taking place and observed that the animals would reappear when noise ceased. Singer (1978) found that mountain goats in Glacier National Park crossed U.S. Highway 2 to reach a salt lick when there was little or no traffic. He documented the following five possible responses of goats to Highway 2 and associated traffic in Glacier National Park: (1) unsuccessful crossing attempts; (2) separation of nannies from kids; (3) alterations of crossing routes; (4) apparent alteration of crossing times; and (5) alteration of normal goat behavior.

Deer, Elk and Moose:

Stubbs and Markham (1979) reported that increased road access due to oil and gas activity is causing declines in deer and elk populations in Alberta, where the normal well spacing is one every quarter section for an oil field and one every section for gas. Schallenberger (1977) reported that many acres of habitat have been lost to grizzly bear in Alberta because of all-weather oil and gas access roads, well sites, pipeline heater and pump buildings, railroads, and processing plants. Ditches, heavy traffic, and deep snowdrifts along oil and gas access roads hinder the movement of wildlife during some periods of the winter (Schallenberger 1977).

PRISM (1982) presented a literature review of the effects of roads on mule deer and white-tailed deer and concluded that:

1) Traffic volumes are directly related to the number of deer killed by vehicle-deer collisions.

2) Deer may avoid roads for unknown reasons but also can become habituated to roads and traffic.

3) Increased deer harvest, resulting from increased hunter use of access networks, can lead to overharvests of herds.

Rost and Bailey (1979) studied the distribution of mule deer and elk in relation to roads in Colorado. They found that mule deer avoid roads more in open shrubland wintering areas than in areas with denser tree cover. Deer also avoided heavily traveled roads more than less traveled roads. In open shrubland winter range, mule deer avoided suitable habitat less than 300 yards from roads. These researchers suggested that both elk and mule deer may avoid roads to an extent that is detrimental to their ability to obtain sufficient forage on winter range.

Edwards (1983) analyzed the impacts of oil and gas leasing on the Custer National Forest of southeastern Montana and suggested that roads and their associated traffic are the single largest source of oil and gas impacts on wildlife. He calculated that 75.2 acres of wildlife habitat were lost for each mile of road constructed. This value was obtained by assuming that wildlife habitat within 100 yards of roads was not used by big game animals.

The impact of roads on elk in Montana has been studied by Lyon (1975), Marcum (1976), Lyon et al. (1981), and Aderhold (1982). These studies show that elk are displaced from roads (the displacement distance depending upon terrain, traffic, and other factors), particularly during hunting season. Hunting pressure significantly influences elk distribution and habitat use, especially where road access is a factor.

Moose are similar to elk and deer in that they are subject to overharvest resulting from increased road access. PRISM (1982) reported that development of large oil and gas fields in Alberta with the accompanying intensive road access network and hunting caused a population decline of moose. Most hunting took place with 1.6 kilometers of roads.

Consequences and Wildlife Impacts

Numerous studies have shown that the primary impacts of roads on big game are associated with the loss of secure habitat and the resultant reduction in hunting opportunity and quality. The presence of numerous roads allows hunters to rapidly penetrate big game security areas, thereby allowing a very high rate of kill during the first few days of the hunting season. Increased vulnerability of animals as a result of more roads results in more restrictive hunting regulations, shorter seasons, and ultimately hunting will be allowed by permit only.

The recognition that access roads adversely affect habitat security and hunting opportunity and quality has resulted in attempts to reduce or avoid these impacts through road closures. The success of road closure has been highly variable throughout western Montana. In the Spotted Bear area, for example, road closures have been effective in keeping out an estimated 95 percent of unauthorized vehicles, whereas in the Tally Lake area, road

closures were less than 50 percent effective (Montana Department of Fish, Wildlife and Parks 1983).

No road closures have been 100 percent effective in restricting unauthorized vehicle use. It is virtually impossible to prevent trail bikes and all-terrain vehicles from skirting gates or barriers.

Besides physical breaching of gates to prevent access, administrative or policy decisions can neutralize the function of a physically secure gate. Public pressure on the U.S. Forest Service (USFS) is effective in reversing road closures. A particularly good example of where a road closure was reversed by administrative decision, to the detriment of wildlife, was in the Long Tom study area (Montana Department of Fish, Wildlife and Parks 1983). The Long Tom study area near Wise River, Montana, was one of the primary sites used to collect data for the 10-year cooperative state/federal elk-logging study (Lyon et al. 1982). After seven years of data acquisition, it was deemed essential for scientific purposes to close the existing roads to monitor how roads without traffic influence elk behavior and habitat utilization. Public desire to use the roads for firewood gathering resulted in pressure on the congressional delegation, and USFS opened the gates. The data acquired over seven years were compromised by the opening of the road (Montana Department of Fish, Wildlife and Parks 1983).

Public pressure to open gates to allow access for a diversity of activities including berry picking, firewood gathering, Christmas tree cutting, and snowmobiling results in year-round intrusion on areas that have roads. Even animals that can adapt to some seasonal activities may not be able to tolerate year-round disruption of their habitat (Montana Department of Fish, Wildlife and Parks 1983).

As part of this study, road density on winter range was analyzed. The average miles of road per township and per section for 46 representative townships in winter ranges throughout Montana were tabulated. The average road density varied from .74 to .98 mile of roads per section, ranging from a low of .28 mile per section to a high of 1.36 miles of road per section. Table 6-5 summarizes the results of this effort.

Table 6-5. Miles of Road on Winter Range for 46 Representative Townships.

Region	Miles of Road/Township	Miles of Road/Section
Overthrust	31.3 miles	0.87 mile
Northern	28.0 miles	0.78 mile
Williston Basin	30.7 miles	0.85 mile
Central	35.7 miles	0.98 mile
Big Horn	26.5 miles	0.74 mile
Powder River	28.8 miles	0.80 mile

The road densities on winter ranges are about the same for all of the oil and gas development regions. This is probably because winter ranges are relatively accessible. In western Montana, for example, winter ranges are adjacent to valleys where rural and suburban development is typically dense.

In nonmountainous parts of Montana, the rolling terrain is crossed by roads for agricultural and recreational purposes. Although there are no data by which to evaluate the quality of winter range as a function of road density, it is assumed that the exiting density of roads on winter ranges is not sufficiently high to eliminate the use of the areas by wildlife.

Although the precise correlation between roads and quality of winter range is not known, it is certain that at some level, new roads reduce the carrying capacity of winter range. The decrease would be due to direct habitat loss, displacement or stress reactions, or combinations of these.

Despite the lack of information concerning the precise nature of the relationship between carrying capacity losses on winter range and increased roads, existing roads were studied and the number of roads likely to accompany oil and gas development were predicted. The estimates of roads likely to result from oil and gas development were derived by measuring roads in the Cedar Creek Anticline oil and gas field and by reviewing reports on oil and gas projects.

Roads in the Cedar Creek Anticline were measured for 26 sections of land that have one to eight wells per section. There does not appear to be a consistent correlation between the amount of road and number of wells per section; however, the most road per well is required when there are only one or two wells per section. The average road length in the Cedar Creek anticline for all sections with one to eight wells per section is 2.3 miles. Table 6-6 summarizes miles of road per well in this area.

It appears that in nonmountainous terrain such as the Cedar Creek Anticline, the miles of new road required per section and per well are less than required in mountainous terrain. Technical Appendix 1 projects that oil and gas development in the mountainous western region would require an average of 1 to 5 miles of new access road per well. According to the U.S. Bureau of Land Management (1981a), an oil field with 40 acres per well and 16 wells per section requires at least 4 miles of access road per section.

In mountainous terrain, the amount of new road needed for well development is quite variable, depending on several factors including existing access and terrain in an area. For example, construction of a single gas well in the Badger-Two Medicine area of the Rocky Mountain Front would require from 4.6 to 9.2 miles of new road (U.S. Bureau of Land Management and U.S. Forest Service 1985).

Hunting and Poaching

Natural resource developments typically are associated with increased killing of wildlife through poaching and heavier hunting pressure. Environmental Research and Technology, Inc. (1983c) reported that oil and gas workers may have a greater impact on wildlife than local residents. Studies in Wyoming show that oil and gas workers participate in more hunting, fishing, camping, and driving recreational vehicles than local residents. The influx of oil and gas workers to the Riley Ridge Project in Wyoming led to a 100 percent increase in poaching and game violations (Johnson 1986).

Table 6-6. Miles of Road per Well in the Cedar Creek Anticline.

Number of Wells/Section	Miles of Road/Section	Miles/Well
4	2.2 miles	0.6 mile
2	1.2 miles	0.6 mile
2	0.9 miles	0.4 mile
8	3.2 miles	0.4 mile
4	2.8 miles	0.7 mile
2	1.1 miles	0.6 mile
6	2.0 miles	0.3 mile
3	1.9 miles	0.6 mile
3	1.8 miles	0.6 mile
7	2.9 miles	0.4 mile
7	3.4 miles	0.5 mile
5	3.4 miles	0.7 mile
6	2.8 miles	0.5 mile
6	2.1 miles	0.4 mile
4	2.4 miles	0.6 mile
7	3.5 miles	0.5 mile
4	3.2 miles	0.8 mile
1	1.8 miles	1.8 miles
1	2.0 miles	2.0 miles
1	1.8 miles	1.8 miles
6	2.8 miles	0.5 mile
2	1.2 miles	0.6 mile
4	1.7 miles	0.4 mile
4	2.8 miles	0.7 mile
5	2.5 miles	0.5 mile
3	1.4 miles	0.5 mile

Average Miles of Road/Section = 2.3 miles

According to the Teton County Comprehensive Plan (1981), significant increases in population would be expected with major oil and gas discoveries in Montana.

Thomas (1983) conducted an in-depth study on game violations perpetrated by workers attracted to various energy development projects in rural western areas. She estimated that there actually are nine times more game violations committed than are reported around the development, and that the illegal big game harvest equals or exceeds the legal harvest.

Habitat Loss and Degradation

The construction and operation of wells, roads, pipelines, transmission lines, and processing facilities would directly remove or degrade wildlife habitat. Small mammals, bird nestlings, reptiles, and amphibians would die, and larger, more mobile species would be displaced.

Animals react differently to disturbance at different times of the year; therefore, year-round disturbance to wildlife and habitat from a variety of human activities is potentially harmful. Animals could be displaced from prime habitat to less desirable areas where food, cover, and protection from predation is inadequate, resulting in population declines.

Habitat removal and degradation would be particularly detrimental if critical wintering, migration, breeding, feeding, and security areas were affected. Wildlife studies in Wyoming show that the development of a gas well field rendered 11,600 acres unusable to wintering elk (Harju 1985). The activity caused by the drilling of three wells was sufficient to cause elk to abandon 6,000 acres of winter range (Johnson 1985). The Wyoming studies led researchers to conclude that continued development of the well field might lead to complete abandonment of ranges and a decline in the elk population.

Kuck et al. (1985) reported that elk calves react strongly to humans and noise by abandoning preferred habitat and moving to marginal habitat. Because marginal habitats often are colder and have suboptimal cover and feed, fewer calves survive. Displacement of elk and bighorn sheep from calving and winter ranges could result in increased levels of predation, excessive expenditures of energy, reduced food intake opportunities, and increased stress-related disease (Irwin and Gillin 1984).

Studies in North Dakota (Lynott and McKenna 1980, McKenna and Lynott 1980) show that roads for oil and gas projects often have been constructed in woody draws and riparian areas, some of the most productive habitat in the northern Great Plains. Development of oil wells in western North Dakota has reduced the carrying capacity of the range for bighorn sheep and mule deer.

Habitat degradation also has been documented in North Dakota due to the emission of airborne sulfur compounds from gas and oil wells. Bilderback (1987) found that toxic, airborne gases from hydrocarbon wells killed or reduced growth in sensitive species of vegetation. Elevated sulfur and sodium levels were associated with tissue damage in mosses and vascular plants collected near the Lone Butte oil field. Bilderback attributed the high sulfur levels to hydrogen sulfide emissions from oil wells and sodium from brine dispersed during a well blowout.

Rosgaard (1983) said that the greatest potential for direct impacts of resource development on black bears occurs in the spring, a critical time when bears must regain weight lost during hibernation. During the spring, bears spend extended periods feeding on open slopes and meadows where they are most visible and, therefore, more vulnerable to hunters. The breeding season for black bears also begins in the spring.

Although hardwood draws comprise less than 1 percent of the landscape in the Northern Great Plains (Girard et al. 1987), the aesthetic, scientific, economic, and wildlife values of these draws are disproportionately large. Hardwood draws are important year-round habitat for mule deer and critical winter habitat for white-tailed deer (Severson and Carter 1978, Swenson 1981). Swenson (1981) found that draws are excellent wildlife habitat. His research indicates that such habitat provides important escape cover, travel corridors, late summer and winter forage, and fawning grounds for white-tailed and mule deer. During the fall and winter months, wooded draws are critical habitat for sharp-tailed grouse, particularly when snow makes grainfields inaccessible (Swenson 1981). Thompson (1978) reported that although wooded draws comprise approximately 1 percent of available habitat in McCone County, 5 percent of all mule and white-tailed deer observations, and nearly 10 percent of sharp-tailed grouse observations were made in these communities.

Besides providing important habitat for big game and game bird species, hardwood draws are essential habitat for a large number of nongame species. Grosz et al. (1981 in Girard 1985) studied wildlife use of hardwood draws in west-central North Dakota. They found that hardwood draws are a center of activity for most species and are of critical importance to many species during the stressful winter months. They also found that hardwood draws support a greater diversity and density of birds than adjacent grasslands and that woodland vegetation is essential to the reproductive success of many of them.

Hopkins (1984) recorded species of birds nesting in hardwood draws in northwestern North Dakota. Although they had lower species diversity than bottomland forests, hardwood draws supported a much higher density of breeding pairs. Hardwood draws also provide important habitat for such nongame mammals as coyote, weasel, red fox, and bobcat (Swenson 1981, Sieg et al. 1984).

The importance of hardwood forests as wildlife habitat and sources of firewood has been put in economic terms by Bjugstad and Sorg (1984). Their study estimated a total annual value of $38 million for the following activities in hardwood draws in the Northern High Plains: deer hunting, $26 million; turkey hunting, $1 million; fur trapping, $4 million; and firewood cutting, $7 million.

Wetlands such as swamps and potholes also provide critical breeding habitat to waterfowl and habitat for big game. Pine Butte and Black Leaf swamps, along the Rocky Mountain Front, are the last areas in the continental United States where grizzly bear still migrate onto the plains to feed (Lesica 1986). Data from Aune and Stivers (1983) show that this wetland complex is heavily used by grizzly bear and is an essential habitat component of the bear in the northern Continental Divide ecosystem.

The U.S. Forest Service (1980) reported that open mud pits, sumps, and evaporation pits constructed during gas and oil extraction may trap and drown animals (especially big game) attempting to obtain water. Waterfowl attracted to mud pits commonly die from eating toxic chemicals and oil, and from having their feathers coated with these substances. Mud pits, due to concentrations of salts, oils, and other chemicals, are usually the last water to freeze and the first to thaw, making them especially attractive to migrating waterfowl (Washington Department of Fish and Game 1980).

Stress

Big Game Animals:

Stress can induce complex physiological changes that affect survival and reproduction. Chronic stress produces chemical changes in the blood which inhibit antibody production, reduce the numbers of white blood cells, and inhibit healing (Irwin and Gillin 1984). Stress also can predispose animals to diseases which can cause significant population declines. Reduced resistance to pneumonia was implicated in a stress-related die-off of bighorn sheep in Colorado due to road and dam construction (Irwin and Gillin 1984). Woodward et al. (1974) reported that subdivision development and livestock grazing in Colorado displaced bighorn sheep to higher elevations during the lambing season. This displacement was thought to cause an observed 80 percent increase in the incidence of pneumonia in young sheep due to harsher weather conditions of the higher elevation.

Acute stress, caused by harassment or irregular and unexpected noise and activity, can be most detrimental during critical times such as in late winter, late pregnancy, and at calving time (Geist 1971). Exertion, particularly during cold weather, can cause emphysema, embryo resorption, abortion, reduced ovulation, and pregnancy toxaemia (Irwin and Gillin 1984, Washington Department of Game and Fish 1980). When excited, ruminants such as sheep, deer, elk, and antelope are less inclined to feed and often eat less nutritious foods which can lead to weight loss, malnutrition, and increased death rates (Irwin and Gillin 1985).

Grouse and Raptors:

Disturbance by humans also can stress birds. Baydack and Hein (1987) found that male sharp-tailed grouse were not displaced from strutting grounds by experimental disturbances such as snow fencing, parked vehicles, exploding devices, scarecrows, taped voices, radio sounds, and a leashed dog. They were, however, displaced by human presence. Female sharptails, in contrast to males, abandoned the strutting grounds in response to the experimental disturbances. Baydack and Hein (1987) suggested that disturbance could render a breeding area reproductively inactive due to the sensitivity of female grouse.

Braun (1986) reported that sage grouse numbers declined on strutting grounds within 2,000 yards of surface coal mining activities. The numbers of male grouse on the strutting grounds declined precipitously over a 5-year period and the grounds were expected to be abandoned. The loss in breeding activity within 2,000 yards of mining was attributed to failure of yearling

male grouse to go to the strutting grounds. It was not known why the grouse stayed away from the strutting grounds.

Human activities also can have a significant influence on feeding behavior of bald eagles (Stalmaster and Newman 1978). The approach of humans within 100 yards of wintering eagles causes them to fly away, which can interfere with food gathering.

Suter and Jones (1981) reported that energy development and other human activities can diminish raptor populations by altering habitats and disturbing nesting activities. Disturbance of nesting raptors can result in desertion of nests, eggs, or young. Suter and Jones recommended that oil and gas pipelines and roads be kept at least 400 yards from areas of prey concentration, such as colonies of ground squirrels and prairie dogs, and should avoid raptor nests by at least a mile.

Near ferruginous hawk nests in Idaho, White et al. (1979) created disturbances of the type caused by geothermal energy development. The hawks abandoned their nests. White et al. recommended that construction activities should be kept at least 1,000 yards from nests.

Loomis (1983) studied the impact of construction of the Northern Border Pipeline on nesting prairie falcons in eastern Montana. Prairie falcons apparently were not disturbed by construction equipment operating within 200 to 600 feet of the nest if the activity was not visible to birds on the nest. Adult birds were more disturbed by humans on foot within 1,200 feet of the nest than they were by construction equipment.

In Wyoming, the increase in oil and gas activity was reported (Lockman et al 1986) to pose a major source of disturbance to whooping cranes and sandhill cranes. Sandhill cranes also were killed in collisions with a powerline serving a gas processing plant. Lockman et al. said that the primary cause of post-fledging death of whooping cranes in Wyoming is collisions with powerlines.

Habituation

Habituation of wildlife to humans reduces stress associated with noise and other unnatural disturbances, but renders animals more susceptible to confrontations with humans. As animals become accustomed to roads and operation of machinery, collisions between animals and vehicles increase.

According to Freddy et al. (1986), mule deer do not readily habituate to human disturbance and are more sensitive to persons on foot than are mountain sheep or elk. Mule deer reacted to humans at greater distances than elk or mountain sheep and also ran greater distances when encountering humans on foot, resulting in significant energy depletion. Ihsle-Pac (1985) conducted studies on the Rocky Mountain Front in Montana and reported that mule deer are easily habituated to oil and gas development if the disturbances are predictable and stationary.

Besides mortality from collisions with vehicles, machinery, and other structures, habituation often leads to animals becoming "problems." Black bear and grizzlies, in particular, are attracted to concentrations of humans,

especially where food, garbage, and sewage are accessible to animals (Bromley 1985). When bears become habituated to humans, they often have to be destroyed because their lack of fear of people directly threatens human safety.

Examples of danger to humans by habituated black bear and grizzly bear have been well documented. Herrero (1985) reported that habituation of bears to humans has led to many human injuries and some deaths but that habituated bears are usually killed by hunters, poachers, or animal control biologists.

Harding and Nagy (1977) studied the impacts of oil and gas development on grizzly bear in Canada and found that bears habituate to work camps and become problem bears. They also reported that oil and gas development affects grizzlies through losses of habitat and disturbance during hibernation.

Toxic Substances

Direct mortality to wildlife can occur from toxic gases and chemicals produced or used in hydrocarbon extraction. Toxic gases such as hydrogen sulfide have been released from wells during "blowouts" in Alberta and Wyoming and have killed moose, elk, domestic livestock, and smaller less mobile wildlife species (Horejsi 1987). Edwards (1985) reported that oil exploration and production sites often result in poisoning of wildlife from ingestion of crude oil, condensate, salt water, caustic chemicals, and heavy metals.

DeJong (1980) reported that liquid chemical spills are a major problem in the oil industry in Canada. Approximately 50 percent of all oil spills reported in Alberta were caused by corrosion of pipelines with the remaining spills coming from battery sites and wellheads. According to DeJong, as oil fields are depleted, brine production increases and higher pipeline pressures are used, which increase the frequency of spills due to more leaks and ruptures.

Girard and Stotts (1986) studied the direct impacts of oil and gas development in the Little Missouri National Grasslands of North Dakota. They reported that toxic chemicals from seepage, spills, and blowouts of saltwater, crude oil, and hydrogen sulfide cause direct impacts to wildlife and habitat, particularly in drainageways and depressions. They estimated that 200 saltwater contaminated areas ranging from 1/4 acre to 70 acres exist in the Little Missouri National Grasslands. Crude oil spills were less common and less damaging to vegetation than brine spills. A saltwater blowout in 1982 with flows of 3,600 gallons per minute and chloride concentrations of 320,000 parts per million destroyed more than 70 acres of vegetation and damaged 200 to 300 acres of juniper and grassland downwind. A number of livestock and wildlife deaths were attributed to hydrogen sulfide fumes, and coniferous trees showed symptoms of sulfur toxicity from airborne emissions.

The escape of hydrogen sulfide from wells is of particular concern due to its extreme toxicity and because it is heavier than air and can settle in depressions and low-lying areas. The most productive and diverse habitats in Montana are sunken areas such as potholes, swamps, marshes, hardwood draws, and riparian habitats. Hydrogen sulfide could have a severe impact on these extremely important habitats and their associated wildlife. Silverman and

Tomlinson (1984) said that riparian vegetation is of significant ecological importance where upland vegetation is predominantly grassland. Riparian areas provide essential food, cover, and habitat for a diversity of birds and animals that could not survive without this environment. Wildlife is attracted to riparian areas because the diverse vegetation provides increased humidity, shade, and critical breeding cover.

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
ARMSTRONG SPRING CREEK	Park	DEPUY'S DIVERSION DAM - ORIGINAL MOUTH	YELLOWSTONE RIVER SEC 08A	0.5	1
BAPTISTE CREEK	Flathead	SOURCE - 300 M ABOVE ROAD 38	HUNGRY HORSE RESERVOIR	4.8	1
BEAR CREEK	Park	DARROCH CREEK - MOUTH	YELLOWSTONE RIVER SEC 09	11.7	1
BEAVERHEAD RIVER	Beaverhead	CLARK CANYON DAM - GRASSHOPPER CREEK	JEFFERSON RIVER	20.4	1
BEEFSTRAIGHT CREEK	Silver Bow	700 M ABOVE AMERICAN GULCH - MOUTH	GERMAN GULCH	3.7	1
BELMONT CREEK	Missoula	HEADWATERS - MOUTH	BLACKFOOT RIVER	12.9	1
BIG CREEK	Flathead	1.5 KM ABOVE NICOLA CREEK - 1 KM ABOVE ELELEHUM CR	N FK FLATHEAD RIVER	7.9	1
BIG CREEK	Flathead	1 KM ABOVE ELELEHUM CREEK - MOUTH	N FK FLATHEAD RIVER	10.4	1
BIG HOLE RIVER SEC 01	Madison	DIVIDE - MOUTH	JEFFERSON RIVER	79.7	1
BIG HOLE RIVER SEC 02	Beaverhead	PINTLAR CREEK - WISE RIVER	JEFFERSON RIVER	50.4	1
BIG HOLE RIVER SEC 02	Beaverhead	WISE RIVER - DIVIDE	JEFFERSON RIVER	18.8	1
BIG HOLE RIVER SEC 03	Madison	SKINNER LAKE - PINTLAR CREEK	JEFFERSON RIVER	54.4	1
BIG LAKE CREEK	Beaverhead	NATIONAL FOREST - MOUTH	BIG HOLE RIVER	17.4	1
BLACKFOOT RIVER SEC 01	Missoula	CLEARWATER RIVER - MOUTH	CLARK FORK RIVER	52.9	1
BOBTAIL CREEK	Lincoln	TERGE CREEK - MOUTH	KOOTENAI RIVER	14.7	1
CEDAR CREEK	Park	N FK CEDAR CREEK - MOUTH	YELLOWSTONE RIVER SEC 09	5.6	1
CLACK CREEK	Flathead	2.8 KM ABOVE MOUTH - MOUTH	M FK FLATHEAD RIVER	2.8	1
COAL CREEK	Flathead	HEADWATERS - N HEADWATER	N FK FLATHEAD RIVER	2.0	1
COAL CREEK	Flathead	N HEADWATER - 2.2 KM ABOVE S FK COAL CREEK	N FK FLATHEAD RIVER	10.5	1
COAL CREEK	Flathead	2.2 KM ABOVE S FK COAL CREEK - 0.6 KM ABOVE DEAD H	N FK FLATHEAD RIVER	8.4	1
COAL CREEK	Flathead	0.6 KM ABOVE DEAD HORSE CREEK - MOUTH	N FK FLATHEAD RIVER	10.1	1
CYCLONE CREEK	Flathead	CYCLONE LAKE - N END CYCLONE PARK	COAL CREEK	4.0	1
CYCLONE CREEK	Flathead	N END CYCLONE PARK - MOUTH	COAL CREEK	2.5	1
DEMPSEY CREEK	Powell	HEADWATERS - N FK DEMPSEY CREEK	CLARK FORK RIVER	11.5	1
DEPUY CREEK	Flathead	SOURCE - MOUTH	CANYON CREEK	4.0	1
DOUGLAS CREEK	Granite	HEADWATERS (N & M FORK) - SETTLING POND	FLINT CREEK SEC 01	3.9	1
DUTCHMAN CREEK	Jefferson	N & S FORKS - BOULDER FIELD	PRICKLY PEAR CREEK	1.3	1
E FK DRY CREEK	Sanders	SOURCE - JUNCTION WITH W FK DRY CREEK	DRY CREEK	9.6	1
E FK ROCK CREEK	Granite	E FK RESERVOIR - MOUTH	ROCK CREEK	12.9	1
EAST TWIN CREEK	Missoula	180 M ABOVE XING - LOWEST RD XING	BLACKFOOT RIVER	0.2	1
EMIGRANT SPRING CREEK	Park	ORIGIN - MOUTH	YELLOWSTONE RIVER SEC 08B	1.6	1
FELIX CREEK	Flathead	2.5 KM ABOVE MOUTH - MOUTH	HUNGRY HORSE RESERVOIR	2.5	1
FELIX CREEK	Flathead	3.8 KM ABOVE MOUTH - 2.5 KM ABOVE MOUTH	HUNGRY HORSE RESERVOIR	1.3	1
FISHER RIVER	Lincoln	WOLF CREEK - MOUTH	KOOTENAI RIVER	18.0	1
FISHER RIVER	Lincoln	LOON LAKE - WOLF CREEK	KOOTENAI RIVER	51.8	1
FLATHEAD RIVER SEC 02	Flathead	FOYS BEND - FLATHEAD LAKE	CLARK FORK RIVER	28.2	1
FLATHEAD RIVER SEC 02	Flathead	S FK FLATHEAD RIVER - FOYS BEND	CLARK FORK RIVER	38.0	1
FLATHEAD RIVER SEC 02	Flathead	N & M FK FLATHEAD RIVER - S FK FLATHEAD RIVER	CLARK FORK RIVER	14.3	1
GALLATIN RIVER SEC 02	Gallatin	SPANISH CREEK - GALLATIN GATEWAY	MISSOURI RIVER	15.7	1
GALLATIN RIVER SEC 03	Gallatin	W FK GALLATIN RIVER - SPANISH CREEK	MISSOURI RIVER	32.8	1
GERMAN GULCH	Silver Bow	BEEFSTRAIGHT CREEK - MOUTH	SILVER BOW CREEK	4.5	1
GERMAN GULCH	Silver Bow	HEADWATERS - BEEFSTRAIGHT CREEK	SILVER BOW CREEK	4.5	1

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
GILBERT CREEK	Missoula	RESERVOIR - MOUTH	ROCK CREEK	4.0	1
GOLD CREEK	Missoula	END OF RD - MOUTH	BLACKFOOT RIVER	17.4	1
GOVERNOR CREEK	Beaverhead	NATIONAL FOREST - MOUTH	BIG HOLE RIVER	18.3	1
GRANITE CREEK	Missoula	HEADWATERS - MOUTH	LOLO CREEK	12.0	1
GRANITE CREEK	Flathead	7.9 KM ABOVE MOUTH - MOUTH	M FK FLATHEAD RIVER	7.9	1
GRANITE CREEK	Flathead	JCT DODGE/CHALLENGE CREEKS - 7.9 KM ABOVE MOUTH	M FK FLATHEAD RIVER	5.5	1
HALFWAY CREEK	Jefferson	HEADWATERS - HALFWAY PARK	BIG PIPESTONE CREEK	2.0	1
HALLOWAT CREEK	Flathead	4 KM ABOVE LAST BRIDGE - 4.1 KM ABOVE MOUTH	BIG CREEK	8.7	1
HALLOWAT CREEK	Flathead	4.1 KM ABOVE MOUTH - MOUTH	BIG CREEK	4.1	1
HARVEY CREEK	Granite	HEADWATERS - RAILROAD DROP STRUCTURE	CLARK FORK RIVER SEC 03	26.5	1
HAY CREEK	Flathead	HAY LAKE - BRIDGE 2 KM BELOW HAY LAKE	N FK FLATHEAD RIVER	1.9	1
HELL ROARING CREEK	Beaverhead	HELL ROARING CANYON - NEW MOUTH	RED ROCK CREEK	1.6	1
HOGBACK CREEK	Granite	HEADWATERS - MOUTH	ROCK CREEK	5.0	1
JOHNSON GULCH	Missoula	75 M ABOVE MOUTH - MOUTH	BLACKFOOT RIVER	0.1	1
KNIEFF CREEK	Flathead	SOURCE - 1.2 KM ABOVE MOUTH	HUNGRY HORSE RESERVOIR	4.0	1
KOOTENAI RIVER	Lincoln	LIBBY DAM - FALLS	COLUMBIA RIVER	43.1	1
KOOTENAI RIVER	Lincoln	FALLS - STATE LINE	COLUMBIA RIVER	32.8	1
LAMBRECHT CREEK	Beaverhead	UPPER END OF JERKED PRAIRIE - LOWER END OF JERKED	PATTENGAIL CREEK	3.0	1
LANGFORD CREEK	Flathead	MUD LAKE - 0.5 KM ABOVE BIG CREEK RD	BIG CREEK	2.0	1
LANGFORD CREEK	Flathead	0.5 KM ABOVE BIG CREEK RD - MOUTH	BIG CREEK	1.2	1
LIBBY CREEK	Lincoln	HWY 2 BRIDGE - MOUTH	KOOTENAI RIVER	20.8	1
LIBBY CREEK	Lincoln	HEADWATERS - HWY 2 BRIDGE	KOOTENAI RIVER	21.4	1
LID CREEK	Flathead	SOURCE - HUNGRY HORSE RESERVOIR	HUNGRY HORSE RESERVOIR	4.0	1
LITTLE SALMON RIVER	Flathead	CHASM CREEK - MOUTH	S FK FLATHEAD RIVER	8.7	1
LOCKE CREEK	Park	DIVERSION DAM - MOUTH	YELLOWSTONE RIVER SEC 07B	0.5	1
LOST JOHNNY CREEK	Flathead	SOURCE - FALLS	S FK FLATHEAD RIVER	9.3	1
LOWER WILLOW CREEK	Granite	SOURCE - WILLOW CREEK RESERVOIR	FLINT CREEK	8.0	1
M FK DOUGLAS CREEK	Granite	HEADWATERS - MOUTH	DOUGLAS CREEK	1.9	1
M FK FLATHEAD RIVER	Flathead	HARRISON CREEK - MOUTH	FLATHEAD RIVER	22.5	1
M FK FLATHEAD RIVER	Flathead	WALTON RANGER STATION - HARRISON CREEK	FLATHEAD RIVER	40.2	1
M FK FLATHEAD RIVER	Flathead	BOWL CREEK - WALTON RANGER STATION	FLATHEAD RIVER	85.3	1
M FK ROCK CREEK	Granite	COPPER CREEK - MOUTH	ROCK CREEK	23.7	1
MADISON RIVER SEC 01	Gallatin	GREYCLIFF ACCESS - MOUTH	MISSOURI RIVER	37.0	1
MADISON RIVER SEC 01	Gallatin	ENNIS LAKE - GREYCLIFF ACCESS	MISSOURI RIVER	20.9	1
MADISON RIVER SEC 02	Gallatin	HEBGEN LAKE - SHEEP CREEK	MISSOURI RIVER	11.6	1
MADISON RIVER SEC 02	Madison	SHEEP CREEK - VARNEY BRIDGE	MISSOURI RIVER	56.3	1
MADISON RIVER SEC 02	Madison	VARNEY BRIDGE - ENNIS LAKE	MISSOURI RIVER	25.7	1
MADISON RIVER SEC 03	Gallatin	YELLOWSTONE PARK - HEBGEN LAKE	MISSOURI RIVER	2.4	1
MARTIN CREEK	Ravalli	BUSH CREEK - MOUTH	MOOSE CREEK	1.6	1
MARTIN CREEK	Ravalli	2194 M ELEVATION - BUSH CREEK	MOOSE CREEK	18.9	1
MATHIAS CREEK	Flathead	CULVERT 1.5 KM ABOVE MOUTH - MOUTH	S FK COAL CREEK	1.5	1
MCCLELLAN CREEK	Jefferson	2 KM ABOVE TEPEE CREEK TRAIL - E FK MCCLELLAN CREE	PRICKLY PEAR CREEK	4.5	1

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
MCGINNIS CREEK	Flathead	SOURCE - FALLS	CANYON CREEK	0.7	1
MINER CREEK	Beaverhead	RIDGE LAKES FK - NATIONAL FOREST	BIG HOLE RIVER	15.3	1
MINER CREEK	Beaverhead	NATIONAL FOREST - MOUTH	BIG HOLE RIVER	9.8	1
MISSOURI RIVER SEC 09	Lewis & Clark	HOLTER DAM - DEARBORN RIVER	MISSISSIPPI RIVER	22.2	1
MISSOURI RIVER SEC 09	Lewis & Clark	DEARBORN RIVER - SHEEP CREEK	MISSISSIPPI RIVER	16.4	1
MISSOURI RIVER SEC 10A	Lewis & Clark	HAUSER DAM - COCHRAN GULCH (HOLTER RES)	MISSISSIPPI RIVER	4.2	1
MISSOURI RIVER SEC 10B	Lewis & Clark	CANYON FERRY DAM - BELOW CANYON FERRY	MISSISSIPPI RIVER	1.8	1
MISSOURI RIVER SEC 11	Broadwater	TOSTON DAM - CANYON FERRY RESERVOIR	MISSISSIPPI RIVER	25.6	1
MOL HERON CREEK	Park	NATIONAL FOREST - MOUTH	YELLOWSTONE RIVER SEC 09	1.0	1
MOL HERON CREEK	Park	CINNABAR CREEK - NATIONAL FOREST	YELLOWSTONE RIVER SEC 09	2.0	1
MOOSE CREEK	Flathead	1 KM BELOW WHALE BUTTES BRIDGE - MOUTH	N FK FLATHEAD RIVER	5.2	1
MOOSE CREEK	Flathead	BRDGE 2 KM ABOVE WHALE BUTTES - 1 KM BELOW WHALE B	N FK FLATHEAD RIVER	4.9	1
MORAN CREEK	Flathead	8 KM ABOVE MOUTH - 7.1 KM ABOVE MOUTH	HAY CREEK	1.4	1
MORAN CREEK	Flathead	DRY AREA BELOW CASCADE - 8 KM ABOVE MOUTH	HAY CREEK	1.8	1
MORRISON CREEK	Flathead	HEADWATERS - PUZZLE CREEK	M FK FLATHEAD RIVER	2.3	1
MORRISON CREEK	Flathead	PUZZLE CREEK - 0.1 KM BELOW CRESCENT CREEK	M FK FLATHEAD RIVER	8.8	1
MORRISON CREEK	Flathead	0.1 KM BELOW CRESCENT CREEK - 1.1 KM BELOW STAR CR	M FK FLATHEAD RIVER	3.8	1
MORRISON CREEK	Flathead	1.1 KM BELOW STAR CREEK - MOUTH	M FK FLATHEAD RIVER	7.5	1
N FK BIG HOLE RIVER	Beaverhead	RUBY CREEK - MOUTH	BIG HOLE RIVER	27.2	1
N FK DOUGLAS CREEK	Granite	HEADWATERS - MOUTH	DOUGLAS CREEK	6.2	1
N FK FLATHEAD RIVER	Flathead	CAMAS CREEK - MOUTH	FLATHEAD RIVER	29.0	1
N FK FLATHEAD RIVER	Flathead	STATE LINE - CAMAS CREEK	FLATHEAD RIVER	37.0	1
N FK GREENHORN CREEK	Madison	HEADWATERS - JUNCTION WITH SOUTH FORK	GREENHORN CREEK	11.9	1
NELSON SPRING CREEK	Park	ORIGIN - MOUTH	YELLOWSTONE RIVER SEC 08A	4.0	1
O'DELL CREEK	Madison	HWY 287 BRIDGE - MOUTH	MADISON RIVER	2.9	1
O'DELL CREEK	Madison	HEADWATERS - HWY 287 BRIDGE	MADISON RIVER	12.9	1
O'KEEFE CREEK	Missoula	HEADWATERS - 2 MI N OF I-90/US-93 WYE	CLARK FORK RIVER	11.3	1
PETERSON CREEK	Park	GREELEY CREEK - MOUTH	YELLOWSTONE RIVER SEC 07B	0.5	1
POINDEXTER SLOUGH	Beaverhead	HEADWATERS - MOUTH	BEAVERHEAD RIVER	8.0	1
POWELL CREEK	Powell	WEST BOUNDARY SECTION 17 - EAST BOUNDARY SECTION 1	CLARK FORK RIVER SEC 04	1.6	1
QUARTZ CREEK	Lincoln	HENNESEY CREEK - MOUTH	KOOTENAI RIVER	14.7	1
QUINTONKIN CREEK	Flathead	POSEY CREEK - MOUTH	SULLIVAN CREEK	9.0	1
QUINTONKIN CREEK	Flathead	SOURCE - POSEY CREEK	SULLIVAN CREEK	6.0	1
RANCH CREEK	Granite	HEADWATERS - MOUTH	ROCK CREEK	14.0	1
RAPE CREEK	Beaverhead	HEADWATERS - IRRIGATION RESERVOIR	HORSE PRAIRIE CREEK	11.3	1
RED MEADOW CREEK	Flathead	RED MEADOW LAKE - LINK LAKE FORK	N FK FLATHEAD RIVER	2.6	1
RED MEADOW CREEK	Flathead	1 KM ABOVE 2ND BRIDGE - MOUTH	N FK FLATHEAD RIVER	7.7	1
RED MEADOW CREEK	Flathead	LINK LAKE FORK - 1 KM ABOVE 2ND BRIDGE	N FK FLATHEAD RIVER	11.6	1
RED ROCK CREEK	Beaverhead	HELLROARING CREEK ORIGINAL MOU - UPPER RED ROCK LA	BEAVERHEAD RIVER	11.2	1
ROCK CREEK	Park	0.3 MI ABOVE GALLATIN CO LINE - MOUTH	YELLOWSTONE RIVER SEC 08B	12.5	1
ROCK CREEK	Beaverhead	NATIONAL FOREST - MOUTH	BIG HOLE RIVER	20.9	1
ROCK CREEK SEC 01	Granite	HOGBACK CREEK - MOUTH	CLARK FORK RIVER	47.0	1

Montana Rivers Study
Rivers with Fisheries Value Class 1
Oil & Gas Region No. 1

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
ROCK CREEK SEC 02	Granite	FORKS - HOGBACK CREEK	CLARK FORK RIVER	33.3	1
ROSS FORK ROCK CREEK	Granite	ELK CREEK - MOUTH	W FK ROCK CREEK	13.2	1
RYLE CREEK	Flathead	SOURCE - MOUTH	TENT CREEK	4.0	1
S FK COAL CREEK	Flathead	HEADWATERS - 2ND BRIDGE ABOVE MOUTH	COAL CREEK	2.0	1
S FK COAL CREEK	Flathead	2ND BRIDGE ABOVE MOUTH - MOUTH	COAL CREEK	9.0	1
S FK DOUGLAS CREEK	Granite	HEADWATERS - MOUTH	M FK DOUGLAS CREEK	2.3	1
S FK FLATHEAD RIVER	Flathead	BUNKER CREEK - HUNGRY HORSE RESERVOIR	FLATHEAD RIVER	27.4	1
S FK FLATHEAD RIVER	Flathead	YOUNG/DANAHER CREEKS - BUNKER CREEK	FLATHEAD RIVER	53.1	1
SANDHOLLOW CREEK	Beaverhead	SOURCE - MOUTH	BIG HOLE RIVER	8.0	1
SCHAFER CREEK	Flathead	0.15 KM BELOW ROUGE CREEK - MOUTH	M FK FLATHEAD RIVER	4.6	1
SHORTY CREEK	Flathead	FALLS 1 KM ABOVE N FK SHORTY C - MOUTH	WHALE CREEK	4.5	1
SKOOKOLEEL CREEK	Flathead	LAKE AT HEADWATERS - 4.8 KM ABOVE MOUTH	BIG CREEK	3.4	1
SLEEPING CHILD CREEK	Ravalli	HEADWATERS - MOUTH	BITTERROOT RIVER	31.4	1
SPANISH CREEK	Gallatin	N & S FK SPANISH CREEK - MOUTH	GALLATIN RIVER SEC 02	4.2	1
SPOTTED BEAR RIVER	Flathead	SOURCE - DEAN FALLS	S FK FLATHEAD RIVER	22.5	1
SPOTTED BEAR RIVER	Flathead	DEAN FALLS - MOUTH	S FK FLATHEAD RIVER	31.5	1
SQUAW CREEK	Gallatin	BUTTE CREEK - MOUTH	GALLATIN RIVER SEC 03	11.3	1
STEEL CREEK	Beaverhead	MOOSE MEADOWS - MOUTH	BIG HOLE RIVER	14.4	1
STONY CREEK	Granite	LAKE SOURCE - MOUTH	ROCK CREEK	14.5	1
STRAWBERRY CREEK	Flathead	0.1 KM ABOVE E FK STRAWBERRY C - TRAIL CREEK	M FK FLATHEAD RIVER	7.5	1
SULLIVAN CREEK	Flathead	SOURCE - 20.9 KM ABOVE MOUTH	S FK FLATHEAD RIVER	4.4	1
SULLIVAN CREEK	Flathead	3.2 KM ABOVE MOUTH - MOUTH	HUNGRY HORSE RESERVOIR	3.2	1
SULLIVAN CREEK	Flathead	10.8 KM ABOVE MOUTH - 3.2 KM ABOVE MOUTH	HUNGRY HORSE RESERVOIR	7.6	1
SULLIVAN CREEK	Flathead	20.9 KM ABOVE MOUTH - 15.3 KM ABOVE MOUTH	HUNGRY HORSE RESERVOIR	5.6	1
SWAMP CREEK	Beaverhead	YANK SWAMP - MOUTH	BIG HOLE RIVER	29.0	1
TELEGRAPH CREEK	Powell	END PRIVATE LAND IN FOREST - BEGIN PRIVATE LAND	LITTLE BLACKFOOT RIVER	4.4	1
TOM MINER CREEK	Park	PINE CREEK - MOUTH	YELLOWSTONE RIVER SEC 08B	10.9	1
TRAIL CREEK	Flathead	BOTTOM OF DRY AREA - MOUTH	N FK FLATHEAD RIVER	11.4	1
UNAWAH CREEK	Flathead	SOURCE - MOUTH	FELIX CREEK	5.0	1
VERMILION RIVER	Sanders	SOURCE - VERMILION FALLS	CLARK FORK RIVER	2.7	1
W FK GALLATIN RIVER	Gallatin	M FK W FK GALLATIN RIVER - MOUTH	GALLATIN RIVER SEC 03	6.9	1
W FK ROCK CREEK	Granite	SOURCE - MOUTH	ROCK CREEK	29.4	1
WELCOME CREEK	Granite	CARRON CREEK - MOUTH	ROCK CREEK	6.6	1
WEST TWIN CREEK	Missoula	50 M ABOVE 1ST BRIDGE - 50 M BELOW 1ST BRIDGE	BLACKFOOT RIVER	0.1	1
WHALE CREEK	Flathead	WHALE CREEK FALLS - 2 KM ABOVE WHALE BUTTES BRIDGE	N FK FLATHEAD RIVER	11.5	1
WHALE CREEK	Flathead	2 KM ABOVE WHALE BUTTES BRIDGE - MOUTH	N FK FLATHEAD RIVER	13.9	1
YELLOWSTONE RIVER SEC 07B	Park	SHIELDS RIVER - SPRINGDALE	MISSOURI RIVER	23.8	1
YELLOWSTONE RIVER SEC 08A	Park	PINE CREEK - SHIELDS RIVER	MISSOURI RIVER	31.5	1
YELLOWSTONE RIVER SEC 08B	Park	TOM MINER CREEK - PINE CREEK	MISSOURI RIVER	52.0	1
YELLOWSTONE RIVER SEC 09	Park	YELLOWSTONE PARK - TOM MINER CREEK	MISSOURI RIVER	27.7	1

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
ADDITION CREEK	Flathead	SOURCE - MOUTH	S FK FLATHEAD RIVER	8.0	2
ANTELOPE CREEK	Madison	SOURCE - MOUTH	CLIFF LAKE/MADISON RIVER	13.2	2
ARGOSY CREEK	Flathead	HEADWATERS - 1.5 KM ABOVE MOUTH	DOLLY VARDEN CREEK	3.7	2
ARGOSY CREEK	Flathead	1.5 KM ABOVE MOUTH - MOUTH	DOLLY VARDEN CREEK	1.5	2
ARRASTRA CREEK	Powell	NATIONAL FOREST - MOUTH	BLACKFOOT RIVER	7.2	2
BABCOCK CREEK	Powell	FURIOUS CREEK - MOUTH	YOUNGS CREEK	11.3	2
BAKER CREEK	Gallatin	I-90 - MOUTH	GALLATIN RIVER SEC 02	3.1	2
BAKER CREEK	Ravalli	HEADWATERS - NATIONAL FOREST	W FK BITTERROOT RIVER	6.4	2
BALL CREEK	Flathead	SOURCE - MOUTH	SULLIVAN CREEK	8.0	2
BALSINGER CREEK	Lewis & Clark	HEADWATERS - MOUTH	TENDERFOOT CREEK	8.2	2
BAR CREEK	Lewis & Clark	SOURCE - MOUTH	DANAHER CREEK	6.4	2
BASIN CREEK	Powell	SOURCE - MOUTH	DANAHER CREEK	11.3	2
BASIN CREEK	Flathead	8.7 KM ABOVE MOUTH - 2.1 KM ABOVE MOUTH	BOWL CREEK	6.6	2
BASIN CREEK	Flathead	2.1 KM ABOVE MOUTH - MOUTH	BOWL CREEK	2.1	2
BATTERY CREEK	Flathead	SOURCE - 1.9 KM ABOVE MOUTH	HUNGRY HORSE RESERVOIR	2.9	2
BATTERY CREEK	Flathead	1.9 KM ABOVE MOUTH - MOUTH	HUNGRY HORSE RESERVOIR	1.9	2
BEAR CREEK	Beaverhead	HEADWATERS - MOUTH	TRAIL CREEK	14.3	2
BEAVER CREEK	Ravalli	HEADWATERS - MOUTH	W FK BITTERROOT RIVER	8.3	2
BEAVERHEAD RIVER	Beaverhead	GRASSHOPPER CREEK - STODDEN DITCH	JEFFERSON RIVER	20.6	2
BIG CREEK	Ravalli	NATIONAL FOREST - MOUTH	BITTERROOT RIVER SEC 01	6.4	2
BIG SALMON RIVER	Flathead	SPUD CREEK - MOUTH	S FK FLATHEAD RIVER	6.3	2
BIG SHEEP CREEK	Beaverhead	SOURCE - SHEARING PEN GULCH	RED ROCK RIVER	12.7	2
BITTERROOT RIVER SEC 01	Missoula	FLORENCE BRIDGE - MOUTH	CLARK FORK RIVER	36.9	2
BITTERROOT RIVER SEC 01	Missoula	BELL XING - FLORENCE BRIDGE	CLARK FORK RIVER	27.4	2
BITTERROOT RIVER SEC 02	Ravalli	E & W FK BITTERROOT RIVER - BELL XING	CLARK FORK RIVER	66.6	2
BLACK SAND SPRING CREEK	Gallatin	HEADWATERS - MOUTH	S FK MADISON RIVER	0.8	2
BLACKFOOT RIVER SEC 02	Missoula	ARRASTRA CREEK - CLEARWATER RIVER	CLARK FORK RIVER	69.2	2
BLAINE SPRINGS CREEK	Madison	ENNIS FISH HATCHERY - MOUTH	MADISON RIVER	8.5	2
BLODGETT CREEK	Ravalli	SOURCE - MOUTH	BITTERROOT RIVER	36.2	2
BLUE JOINT CREEK	Ravalli	HEADWATERS - MOUTH	PAINTED ROCKS LAKE	27.7	2
BOULDER CREEK	Ravalli	HEADWATERS - MOUTH	W FK BITTERROOT RIVER	15.2	2
BOWL CREEK	Flathead	0.6 KM BELOW SCALP CREEK - MOUTH	STRAWBERRY CREEK	2.6	2
BOWL CREEK	Flathead	2.9 KM BELOW BASIN CREEK - 0.6 KM BELOW SCALP CREE	STRAWBERRY CREEK	4.2	2
BOWL CREEK	Flathead	0.1 KM ABOVE BASIN CREEK - 1.5 KM BELOW BASIN CREE	STRAWBERRY CREEK	1.6	2
BRANCH CREEK	Flathead	SOURCE - 3.5 KM ABOVE MOUTH	SULLIVAN CREEK	4.8	2
BRANCH CREEK	Flathead	3.5 KM ABOVE MOUTH - MOUTH	SULLIVAN CREEK	3.5	2
BUCK CREEK	Ravalli	HEADWATERS - MOUTH	E FK BITTERROOT RIVER	4.8	2
BULL RIVER	Sanders	E FK BULL CREEK - MOUTH	CLARK FORK RIVER	13.2	2
BUNKER CREEK	Flathead	FALLS - MOUTH	S FK FLATHEAD RIVER	18.0	2
BUNKER CREEK	Flathead	SOURCE - FALLS	S FK FLATHEAD RIVER	23.2	2
BURNT CREEK	Powell	SOURCE - MOUTH	S FK FLATHEAD RIVER	11.3	2
BUTLER CREEK	Missoula	HEADWATERS - MOUTH	GRASS VALLEY FRENCH DITCH	20.8	2

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
CABIN CREEK	Beaverhead	JEEP TRAIL XING - ROCKY POINT E SEC 1	BIG SHEEP CREEK	1.0	2
CALBICK CREEK	Flathead	4.3 KM ABOVE MOUTH - MOUTH	M FK FLATHEAD RIVER	4.3	2
CALLAHAN CREEK	Lincoln	FALLS - MOUTH	KOOTENAI RIVER	6.9	2
CALLAHAN CREEK	Lincoln	SOURCE - FALLS	KOOTENAI RIVER	12.8	2
CAMP CREEK	Powell	SOURCE - MOUTH	DANAHER CREEK	8.0	2
CEDAR CREEK	Mineral	HEADWATERS - MOUTH	CLARK FORK RIVER	24.8	2
CHAFFIN CREEK	Ravalli	HEADWATERS - NATIONAL FOREST	BITTERROOT RIVER SEC 02	13.9	2
CHALLENGE CREEK	Flathead	HEADWATERS - DODGE CREEK	M FK FLATHEAD RIVER	4.0	2
CLACK CREEK	Flathead	HEADWATERS - 1.9 KM ABOVE TRAIL FORD	M FK FLATHEAD RIVER	5.1	2
CLARK CREEK	Flathead	CONFLUENCE OF HEADWATERS - 2.5 KM ABOVE MOUTH	HUNGRY HORSE RESERVOIR	3.0	2
CLARK CREEK	Flathead	2.5 KM ABOVE MOUTH - MOUTH	HUNGRY HORSE RESERVOIR	2.5	2
CLARK FORK RIVER SEC 02	Mineral	SUPERIOR - SIEGAL CREEK	PEND OREILLE RIVER	68.3	2
CLARK FORK RIVER SEC 02	Mineral	BITTERROOT RIVER - SUPERIOR	PEND OREILLE RIVER	99.6	2
CLARK FORK RIVER SEC 03	Missoula	MILLTOWN DAM - BITTERROOT RIVER	PEND OREILLE RIVER	19.5	2
CLARK FORK RIVER SEC 03	Missoula	ROCK CREEK - MILLTOWN DAM	PEND OREILLE RIVER	28.0	2
CLARK FORK RIVER SEC 04	Powell	WARM SPRINGS CREEK - DEMPSEY CREEK	PEND OREILLE RIVER	20.9	2
CLEARWATER RIVER	Missoula	CLEARWATER LAKE - INEZ LAKE	BLACKFOOT RIVER	9.7	2
COLD SPRINGS CREEK	Jefferson	SOURCE - MOUTH	BOULDER RIVER	0.4	2
COLTS CREEK	Flathead	SOURCE/BRITISH COLUMBIA - MOUTH	N FK FLATHEAD RIVER	1.6	2
CONNOR CREEK	Flathead	SOURCE - MOUTH	SULLIVAN CREEK	7.2	2
COOPER GULCH	Sanders	SOURCE - MOUTH	PROSPECT CREEK	9.7	2
CORRAL CREEK	Beaverhead	BLM LAND - MOUTH	RED ROCK CREEK	7.4	2
COX CREEK	Flathead	3.3 KM ABOVE MOUTH - MOUTH	M FK FLATHEAD RIVER	3.3	2
COX CREEK	Flathead	0.2 KM BELOW BURNT CREEK - 3.3 KM ABOVE MOUTH	M FK FLATHEAD RIVER	6.1	2
CUMMINGS CREEK	Flathead	HEADWATERS - MOUTH	QUARTZ CREEK	11.8	2
DALY CREEK	Ravalli	HEADWATERS - MOUTH	SKALKAHO CREEK	16.4	2
DANAHER CREEK	Powell	RAPID CREEK - 6.8 KM ABOVE MOUTH	S FK FLATHEAD RIVER	10.9	2
DEAD HORSE CREEK	Flathead	HEADWATERS - BRIDGE	COAL CREEK	1.2	2
DEAD HORSE CREEK	Flathead	BRIDGE - MOUTH	COAL CREEK	6.1	2
DEER CREEK	Ravalli	HEADWATERS - NATIONAL FOREST	W FK BITTERROOT RIVER	22.5	2
DICKEY CREEK	Flathead	BARRIER FALLS AT 4.4 KM - MOUTH	M FK FLATHEAD RIVER	4.4	2
DIRTYFACE CREEK	Flathead	1 KM ABOVE ELK CREEK - MOUTH	M FK FLATHEAD RIVER	4.2	2
DODGE CREEK	Flathead	3.7 KM ABOVE MOUTH - MOUTH	GRANITE CREEK	3.7	2
DOLLY VARDEN CREEK	Flathead	0.5 KM ABOVE ARGOSY CREEK - SCHAFER CREEK	M FK FLATHEAD RIVER	13.1	2
DORIS CREEK	Flathead	2.1 KM ABOVE MOUTH - MOUTH	HUNGRY HORSE RESERVOIR	2.1	2
DORIS CREEK	Flathead	5.5 KM ABOVE MOUTH - 2.1 KM ABOVE MOUTH	HUNGRY HORSE RESERVOIR	3.4	2
DRY COTTONWOOD CREEK	Powell	BLM BOUNDARY - BLM BOUNDARY	COTTONWOOD CREEK	4.0	2
DRY CREEK	Mineral	DRY FORK - MOUTH	CLARK FORK RIVER	4.8	2
E FK BITTERROOT RIVER	Ravalli	NATIONAL FOREST - MOUTH	BITTERROOT RIVER	11.4	2
E FK BITTERROOT RIVER	Ravalli	HEADWATERS - NATIONAL FOREST	BITTERROOT RIVER	59.5	2
E FK BULL RIVER	Sanders	HEADWATERS - MOUTH	BULL RIVER	11.3	2
E FK CLEARWATER RIVER	Missoula	HEADWATERS - MOUTH	CLEARWATER RIVER	9.6	2

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
E FK HYALITE CREEK	Gallatin	FLANDERS CREEK - HYALITE RESERVOIR	HYALITE RESERVOIR	3.5	2
E FK STRAWBERRY CREEK	Flathead	3 KM ABOVE MOUTH - MOUTH	M FK FLATHEAD RIVER	3.0	2
EAST GALLATIN RIVER	Gallatin	BOZEMAN CREEK - HYALITE CREEK	GALLATIN RIVER	19.8	2
EAST GALLATIN RIVER	Gallatin	HEADWATERS AT ROCKY CREEK - BOZEMAN CREEK	GALLATIN RIVER	8.5	2
EIGHTMILE CREEK	Ravalli	NORTH FORK - MOUTH	BITTERROOT RIVER SEC 01	13.6	2
ELK CREEK	Missoula	9 KM ABOVE MOUTH - MOUTH	SWAN RIVER	9.0	2
ELK CREEK	Missoula	N & S FK - 9 KM ABOVE MOUTH	SWAN RIVER	7.2	2
EMERY CREEK	Flathead	5.2 KM ABOVE MOUTH - MOUTH	HUNGRY HORSE RESERVOIR	5.2	2
EMERY CREEK	Flathead	CONFLUENCE OF HEADWATERS - 5.2 KM ABOVE MOUTH	HUNGRY HORSE RESERVOIR	4.9	2
FISH CREEK	Mineral	W FK FISH CREEK - MOUTH	CLARK FORK RIVER	23.3	2
FORD CREEK	Flathead	11.7 KM ABOVE MOUTH - 9.5 KM ABOVE MOUTH	N FK FLATHEAD RIVER	3.8	2
FORD CREEK	Flathead	9.5 KM ABOVE MOUTH - 7.2 KM ABOVE MOUTH	N FK FLATHEAD RIVER	2.1	2
FORD CREEK	Flathead	6.9 KM ABOVE MOUTH - MOUTH	N FK FLATHEAD RIVER	6.9	2
FRANCIS CREEK	Beaverhead	HEADWATERS - MOUTH	STEEL CREEK	12.9	2
GALLAGHER CREEK	Powell	HEADWATERS - BLM BOUNDARY	NEVADA CREEK	5.6	2
GALLATIN RIVER SEC 01	Gallatin	EAST GALLATIN RIVER - MOUTH	MISSOURI RIVER	20.1	2
GALLATIN RIVER SEC 02	Gallatin	GALLATIN GATEWAY - CAMERON BRIDGE	MISSOURI RIVER	19.3	2
GALLATIN RIVER SEC 02	Gallatin	BAKER CREEK - EAST GALLATIN RIVER	MISSOURI RIVER	5.1	2
GALLATIN RIVER SEC 03	Gallatin	PARK LINE - W FK GALLATIN RIVER	MISSOURI RIVER	29.0	2
GATEWAY CREEK	Flathead	3.8 KM ABOVE SHIN CREEK - 2 KM ABOVE SHIN CREEK	STRAWBERRY CREEK	1.8	2
GATEWAY CREEK	Flathead	HEADWATERS - 3.8 KM ABOVE SHIN CREEK	STRAWBERRY CREEK	1.1	2
GATEWAY CREEK	Flathead	0.15 KM BELOW SHIN CREEK - MOUTH	STRAWBERRY CREEK	2.5	2
GATEWAY CREEK	Flathead	2 KM ABOVE SHIN CREEK - 0.15 KM BELOW SHIN CREEK	STRAWBERRY CREEK	2.2	2
GOAT CREEK	Lake	5.0 KM ABOVE MOUTH - SQUEEZER CREEK	SWAN RIVER	3.7	2
GOAT CREEK	Lake	1 KM ABOVE SCOUT CREEK - 5 KM ABOVE MOUTH	SWAN RIVER	5.4	2
GOAT CREEK	Lake	SQUEEZER CREEK - MOUTH	SWAN RIVER	1.3	2
GOAT CREEK	Lake	0.1 KM ABOVE BETHAL CREEK - 1.1 KM BELOW BETHAL CR	SWAN RIVER	1.2	2
GOLD CREEK	Ravalli	5520 FT ELEVATION - MOUTH	BURNT FORK BITTERROOT RIVER	5.0	2
GOLD CREEK	Ravalli	FORKS SEC 26 - 5520 FT ELEVATION	BURNT FORK BITTERROOT RIVER	4.1	2
GORDON CREEK	Powell	1.3 KM ABOVE CARDINAL CREEK - 11.9 KM ABOVE MOUTH	S FK FLATHEAD RIVER	3.4	2
GORDON SPRINGS	Beaverhead	SOURCE - MOUTH	BEAVERHEAD RIVER	3.1	2
GROOM CREEK	Lake	3 KM ABOVE MOUTH - MOUTH	SWAN LAKE	3.0	2
HAY CREEK	Flathead	BRIDGE 2 KM BELOW HAY LAKE - 18.5 KM ABOVE MOUTH	N FK FLATHEAD RIVER	7.5	2
HAY CREEK	Flathead	11.3 KM ABOVE MOUTH - MOUTH	N FK FLATHEAD RIVER	10.7	2
HAY CREEK	Flathead	18.5 KM ABOVE MOUTH - 11.3 KM ABOVE MOUTH	N FK FLATHEAD RIVER	7.2	2
HELLS CANYON CREEK	Madison	NATIONAL FOREST - MOUTH	JEFFERSON RIVER	6.4	2
HOGAN CREEK	Jefferson	0.3 KM ABOVE MOUTH - MOUTH	S FK WARM SPRINGS CREEK	0.3	2
HOKE CREEK	Flathead	SOURCE - 1.9 KM ABOVE MOUTH	HUNGRY HORSE RESERVOIR	3.0	2
HUGHES CREEK	Ravalli	HEADWATERS - MOUTH	W FK BITTERROOT RIVER	26.1	2
HUNGRY HORSE CREEK	Flathead	SOURCE - 7.4 KM ABOVE MOUTH	HUNGRY HORSE RESERVOIR	2.9	2
HUNGRY HORSE CREEK	Flathead	3.8 KM ABOVE MOUTH - MOUTH	HUNGRY HORSE RESERVOIR	3.8	2
HUNGRY HORSE CREEK	Flathead	7.4 KM ABOVE MOUTH - 3.8 KM ABOVE MOUTH	HUNGRY HORSE RESERVOIR	3.6	2

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
HYALITE CREEK SEC 02	Gallatin	GROTTO FALLS - HYALITE RESERVOIR	GALLATIN RIVER	3.1	2
INDIAN CREEK	Mineral	HEADWATERS - MOUTH	W FK FISH CREEK	3.2	2
INDIAN CREEK	Beaverhead	0.8 KM ABOVE FS BOUNDARY - 0.8 KM BELOW COUNTY ROA	CABIN CREEK	3.2	2
JEFFERSON RIVER	Broadwater	BIG PIPESTONE CREEK - MOUTH	MISSOURI RIVER	73.1	2
JEFFERSON RIVER	Broadwater	FISH CREEK - BIG PIPESTONE CREEK	MISSOURI RIVER	18.7	2
JEFFERSON RIVER	Gallatin	HEADWATERS - FISH CREEK	MISSOURI RIVER	30.7	2
KETCHIKAN CREEK	Flathead	HEADWATERS - 0.2 KM BELOW JOHNSON CREEK	TRAIL CREEK	3.7	2
KETCHIKAN CREEK	Flathead	2 KM ABOVE MOUTH - MOUTH	TRAIL CREEK	3.0	2
KETCHIKAN CREEK	Flathead	0.2 KM BELOW JOHNSON CREEK - 3 KM ABOVE MOUTH	TRAIL CREEK	1.5	2
KIMMERLY CREEK	Flathead	HEADWATERS - MOUTH	CANYON CREEK	4.2	2
KOOTENAI CREEK	Ravalli	GAUGING STATION AT NF BOUNDARY - MOUTH	BITTERROOT RIVER SEC 01	4.8	2
KOOTENAI CREEK	Ravalli	HEADWATERS - GAUGING STATION AT NF BOUNDARY	BITTERROOT RIVER SEC 01	13.6	2
LAKE CREEK	Flathead	2.5 KM ABOVE MOUTH - MOUTH	M FK FLATHEAD RIVER	2.5	2
LINCOLN CREEK	Flathead	LINCOLN LAKE OUTLET - WALTON CREEK	M FK FLATHEAD RIVER	8.0	2
LION CREEK	Lake	10 KM ABOVE MOUTH - MOUTH	SWAN RIVER	10.0	2
LION CREEK	Park	HEADWATERS - MOUTH	CINNABAR CREEK	4.0	2
LITTLE BLACKFOOT SPRING CR	Powell	SOURCE - MOUTH	LITTLE BLACKFOOT RIVER	4.7	2
LITTLE PRICKLY PEAR CREEK	Lewis & Clark	CANYON CREEK - MOUTH	MISSOURI RIVER	43.0	2
LITTLE ROCK CREEK	Ravalli	HEADWATERS - LAKE COMO	BITTERROOT RIVER SEC 02	9.6	2
LITTLE SALMON RIVER	Flathead	HEADWATERS - CHASM CREEK	S FK FLATHEAD RIVER	16.6	2
LODGEPOLE CREEK	Flathead	1.4 KM ABOVE DRUMMING CREEK - 6.5 KM ABOVE MORRISO	M FK FLATHEAD RIVER	4.1	2
LODGEPOLE CREEK	Flathead	6.5 KM ABOVE MORRISON CREEK - MORRISON CREEK	M FK FLATHEAD RIVER	6.5	2
LOLO CREEK	Missoula	HEADWATERS - MOUTH	BITTERROOT RIVER	45.3	2
LONG BOW CREEK	Flathead	LONG BOW LAKE - MOUTH	AKOKALA CREEK	6.4	2
LONG CREEK	Flathead	0.1 KM ABOVE TRAIL FORD - MOUTH	M FK FLATHEAD RIVER	2.7	2
LONG CREEK	Flathead	MOUTH OF CANYON ABOVE BERGSICK - 0.1 KM ABOVE TRAI	M FK FLATHEAD RIVER	1.3	2
LONG CREEK	Flathead	HEADWATERS - CANYON MOUTH ABOVE BERGSICKER	M FK FLATHEAD RIVER	4.6	2
LOOKOUT CREEK	Flathead	SOURCE - MOUTH	BIG CREEK	4.8	2
LOST CREEK	Deer Lodge	NATIONAL FOREST - MOUTH	CLARK FORK RIVER	24.1	2
LOST JOHNNY CREEK	Flathead	1.0 KM ABOVE MOUTH - MOUTH	HUNGRY HORSE RESERVOIR	1.0	2
LOST MARE CREEK	Flathead	SOURCE - MOUTH	HUNGRY HORSE CREEK	4.8	2
MARGARET CREEK	Flathead	SOURCE - MOUTH	HUNGRY HORSE CREEK	6.4	2
MARION CREEK	Flathead	SOURCE - MOUTH	ESSEX CREEK	3.2	2
MARTEN CREEK	Sanders	N BR MARTEN CREEK - FIR CREEK	NOXON RAPIDS RESERVOIR	1.0	2
MATHIAS CREEK	Flathead	HEADWATERS - CULVERT 1.5 KM ABOVE MOUTH	S FK COAL CREEK	2.8	2
MCDONALD CREEK	Park	HWY 540 - MOUTH	YELLOWSTONE RIVER	3.4	2
MCGINNIS CREEK	Flathead	FALLS - MOUTH	CANYON CREEK	1.3	2
MCMENOMEY SPRINGS	Beaverhead	SOURCE - MOUTH	BEAVERHEAD RIVER	1.4	2
MEADOW CREEK	Ravalli	HEADWATERS - MOUTH	E FK BITTERROOT RIVER	13.0	2
MILL CREEK	Flathead	SOURCE - MOUTH	FLATHEAD RIVER	4.8	2
MILL CREEK	Park	HEADWATERS - MOUTH	CINNABAR CREEK	5.6	2
MILL FORK CREEK	Park	HEADWATERS - MOUTH	MISSION CREEK	5.5	2

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
MONTURE CREEK	Powell	HEADWATERS - MOUTH	BLACKFOOT RIVER	36.2	2
MOORE CREEK	Madison	HIGHWAY 287 IN ENNIS - MOUTH	ENNIS LAKE	8.0	2
MOOSE CREEK	Ravalli	HEADWATERS - MOUTH	E FK BITTERROOT RIVER	13.8	2
MOOSE CREEK	Flathead	3 KM ABOVE ROCK QUARRY - BRDGE 2 KM ABOVE WHALE BU	N FK FLATHEAD RIVER	7.1	2
MORAN CREEK	Flathead	7.1 KM ABOVE MOUTH - MOUTH	HAY CREEK	7.1	2
MUDDY CREEK	Beaverhead	WILSON/SOURDOUGH CREEKS - S BOUNDARY SEC 33	BIG SHEEP CREEK	12.9	2
MUSSIGBROD CREEK	Beaverhead	MUSSIGBROD LAKE - MOUTH	N FK BIG HOLE RIVER	21.5	2
N BR MARTEN CREEK	Sanders	HEADWATERS - MOUTH	MARTEN CREEK	4.5	2
N FK BLACKFOOT RIVER	Powell	HWY 200 BRIDGE - MOUTH	BLACKFOOT RIVER	11.2	2
N FK BLACKFOOT RIVER	Powell	NATIONAL FOREST - HWY 200 BRIDGE	BLACKFOOT RIVER	19.2	2
N FK BLACKFOOT RIVER	Powell	NORTH FORK FALLS - NATIONAL FOREST	BLACKFOOT RIVER	17.7	2
N FK DIVIDE CREEK	Beaverhead	1/2 MILE ABOVE NATIONAL FOREST - OLD RAILROAD GRAD	HORSE PRAIRIE CREEK	4.2	2
N FK DUTCHMAN CREEK	Jefferson	1.1 KM ABOVE MOUTH - MOUTH	DUTCHMAN CREEK	1.1	2
N FK FISH CREEK	Mineral	CRATER CREEK - MOUTH	FISH CREEK	16.7	2
N FK RYE CREEK	Ravalli	HEADWATERS - MOUTH	RYE CREEK	8.6	2
NARROWS CREEK	Beaverhead	HEADWATERS - MOUTH	RED ROCK RIVER	3.5	2
NELSON CREEK	Ravalli	NATIONAL FOREST - MOUTH	NEZ PERCE FORK	0.5	2
NELSON CREEK	Ravalli	HEADWATERS - NATIONAL FOREST	W FK BITTERROOT RIVER	9.9	2
NEVADA CREEK	Powell	NEVADA LAKE - MOUTH	BLACKFOOT RIVER	35.4	2
NEZ PERCE FORK BITTERROOT R	Ravalli	HEADWATERS - MOUTH	W FK BITTERROOT RIVER	20.1	2
NINEMILE CREEK	Missoula	HEADWATERS - MOUTH	CLARK FORK RIVER	39.8	2
NORTH CALLAHAN CREEK	Lincoln	STATE LINE - MOUTH	CALLAHAN CREEK	3.2	2
ODELL CREEK	Beaverhead	COUNTY RD - REFUGE	RED ROCK CREEK	2.9	2
ODELL CREEK	Beaverhead	0.4 KM ABOVE SPRING CREEK - COUNTY RD	RED ROCK CREEK	4.8	2
ODELL CREEK	Beaverhead	REFUGE - LOWER RED ROCK LAKE	RED ROCK CREEK	6.1	2
ODELL CREEK	Beaverhead	HEADWATERS - 0.4 KM ABOVE SPRING CREEK	RED ROCK CREEK	2.4	2
PEET CREEK	Beaverhead	1ST RD XING ABOVE DAM - COUNTY RD XING/JONES RANCH	RED ROCK RIVER	2.8	2
PETTY CREEK	Missoula	SOURCE - MOUTH	CLARK FORK RIVER	18.2	2
PRICKLY PEAR CREEK	Jefferson	4.8 KM ABOVE NATIONAL FOREST - NATIONAL FOREST	LAKE HELENA	4.8	2
PUZZLE CREEK	Flathead	SOURCE - MOUTH	MORRISON CREEK	6.4	2
QUARTZ CREEK	Flathead	LOWER QUARTZ LAKE - MOUTH	N FK FLATHEAD RIVER	10.1	2
RACETRACK CREEK	Powell	RR BRIDGE - HWY BRIDGE	CLARK FORK RIVER	1.5	2
RATTLESNAKE CREEK	Missoula	MOUNTAIN WATER CO DAM - MOUTH	CLARK FORK RIVER SEC 03	8.0	2
RED BUTTE CREEK	Missoula	SOURCE - MOUTH	KRAFT CREEK	4.0	2
RED ROCK RIVER SEC 01	Beaverhead	BIG SHEEP CREEK - MOUTH	CLARK CANYON RESERVOIR	30.4	2
REESE CREEK	Gallatin	SOURCE - MOUTH	EAST GALLATIN RIVER	6.0	2
RIVERSIDE CREEK	Flathead	1.1 KM ABOVE MOUTH - MOUTH	HUNGRY HORSE RESERVOIR	1.1	2
ROARING CREEK	Flathead	SOURCE - MOUTH	SCHAFER CREEK	6.4	2
ROCKY CREEK	Gallatin	JACKSON & TIMBERLINE CREEKS - MOUTH	EAST GALLATIN RIVER	15.5	2
ROMAN CREEK	Missoula	HEADWATERS - MOUTH	CLARK FORK RIVER SEC 02	9.6	2
RUBY RIVER SEC 01	Madison	RUBY RESERVOIR - MOUTH	BEAVERHEAD RIVER	53.9	2
RYE CREEK	Ravalli	N FK RYE CREEK - MOUTH	BITTERROOT RIVER SEC 02	9.6	2

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
RYE CREEK	Ravalli	HEADWATERS - N FK RYE CREEK	BITTERROOT RIVER SEC 02	11.2	2
S BR MARTEN CREEK	Sanders	SOURCE - MOUTH	MARTEN CREEK	5.6	2
S FK DUTCHMAN CREEK	Jefferson	1.0 KM ABOVE MOUTH - MOUTH	DUTCHMAN CREEK	1.0	2
S FK FISH CREEK	Mineral	CACHE CREEK - MOUTH	FISH CREEK	15.6	2
S FK MADISON RIVER	Gallatin	RR LINE - MOUTH	MADISON RIVER	10.0	2
S FK ROSS FORK ROCK CREEK	Granite	HEADWATERS - MOUTH	ROSS FORK ROCK CREEK	8.3	2
S FK TRAIL CREEK	Flathead	HEADWATERS - MOUTH	TRAIL CREEK	4.8	2
S FK WARM SPRINGS CREEK	Jefferson	TRAIL XING - NATIONAL FOREST	WARM SPRINGS CREEK	4.2	2
SAGE CREEK	Flathead	STATE LINE - MOUTH	N FK FLATHEAD RIVER	2.1	2
SAWMILL CREEK	Lewis & Clark	UPPER END OF MEADOWS - MEADOWS	DRY FORK BELT CREEK	3.2	2
SAWTOOTH CREEK	Ravalli	HEADWATERS - NATIONAL FOREST	BITTERROOT RIVER SEC 02	18.9	2
SCALP CREEK	Flathead	SOURCE - MOUTH	BOWL CREEK	4.0	2
SCHAFER CREEK	Flathead	0.4 KM BELOW W FK - 1 KM ABOVE ROUGE CREEK	M FK FLATHEAD RIVER	4.8	2
SCHAFER CREEK	Flathead	1 KM ABOVE ROUGE CREEK - 0.15 KM BELOW ROUGE CREEK	M FK FLATHEAD RIVER	1.1	2
SERGEANT CREEK	Flathead	SOURCE - MOUTH	SPOTTED BEAR RIVER	4.8	2
SHEAFMAN CREEK	Ravalli	NATIONAL FOREST - MOUTH	BITTERROOT RIVER SEC 02	12.5	2
SHEAFMAN CREEK	Ravalli	HEADWATERS - NATIONAL FOREST	BITTERROOT RIVER SEC 02	9.6	2
SHEEPHEAD CREEK	Ravalli	HEADWATERS - MOUTH	NEZ PERCE FK BITTERROOT RIVER	12.3	2
SHORTY CREEK	Flathead	HEADWATERS - FALLS 1 KM ABOVE N FK SHORTY C	WHALE CREEK	4.6	2
SIMPSON CREEK	Beaverhead	HEADWATERS - MOUTH	CABIN CREEK	14.3	2
SIXMILE CREEK	Missoula	HEADWATERS - MOUTH	CLARK FORK RIVER SEC 02	16.0	2
SKALKAHO CREEK	Ravalli	NATIONAL FOREST - MOUTH	BITTERROOT RIVER	12.9	2
SKOOKOLEEL CREEK	Flathead	4.8 KM ABOVE MOUTH - FALLS	BIG CREEK	3.3	2
SLATE CREEK	Ravalli	HEADWATERS - PAINTED ROCKS RESERVOIR	W FK BITTERROOT RIVER	16.8	2
SLIDE CREEK	Flathead	SOURCE - MOUTH	SULLIVAN CREEK	6.4	2
SOLDIER CREEK	Flathead	SOURCE - MOUTH	S FK FLATHEAD RIVER	3.2	2
SOURDOUGH CREEK	Beaverhead	SPRING IN SEC 35 - MOUTH	MUDDY CREEK	0.8	2
SOUTH CALLAHAN CREEK	Lincoln	STATE LINE - MOUTH	CALLAHAN CREEK	4.5	2
SPRING CREEK & TRIBS	Park	HEADWATERS - MOUTH	SHIELDS RIVER	8.0	2
SQUEEZER CREEK	Lake	SOURCE - BRIDGE AT KM 6.5	GOAT CREEK	5.5	2
SQUEEZER CREEK	Lake	BRIDGE AT 6.5 KM - MOUTH	GOAT CREEK	6.5	2
ST REGIS RIVER	Mineral	DE BORGIA - MOUTH	CLARK FORK RIVER	24.5	2
ST REGIS RIVER	Mineral	HEADWATERS - DE BORGIA	CLARK FORK RIVER	29.1	2
STADIUM CREEK	Flathead	SOURCE - MOUTH	GORGE CREEK	4.8	2
STANLEY CREEK	Lincoln	HEADWATERS - BULL LAKE	LAKE CREEK	8.0	2
STAUBACH CREEK	Broadwater	FS RD XING - NATIONAL FOREST	BEAVER CREEK	0.8	2
STRAWBERRY CREEK	Flathead	HEADWATERS - 5.2 KM ABOVE E FK STRAWBERRY C	M FK FLATHEAD RIVER	2.3	2
STRAWBERRY CREEK	Flathead	5.2 KM ABOVE E FK STRAWBERRY C - 0.1 KM ABOVE E FK	M FK FLATHEAD RIVER	5.1	2
STRAWBERRY CREEK	Flathead	TRAIL CREEK - BOWL CREEK	M FK FLATHEAD RIVER	4.9	2
STUART MILL CREEK	Deer Lodge	SOURCE - MOUTH	GEORGETOWN LAKE/FLINT CREEK	0.7	2
STUTCHES SPRING CREEK	Park	ORIGIN (SPRING) - MOUTH	YELLOWSTONE RIVER SEC 08B	0.7	2
SULLIVAN CREEK	Flathead	15.3 KM ABOVE MOUTH - 10.8 KM ABOVE MOUTH	HUNGRY HORSE RESERVOIR	4.5	2

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
SWAN RIVER SEC 02	Flathead	LINDBERGH LAKE - SWAN LAKE	FLATHEAD RIVER	80.1	2
SWEATHOUSE CREEK	Ravalli	NATIONAL FOREST - MOUTH	BITTERROOT RIVER SEC 02	7.6	2
SWEATHOUSE CREEK	Ravalli	HEADWATERS - NATIONAL FOREST	BITTERROOT RIVER SEC 02	9.6	2
TANGO CREEK	Missoula	SOURCE - MOUTH	BIG SALMON RIVER	3.2	2
TEEPEE CREEK	Jefferson	FORKS 1.3 KM ABOVE MOUTH - MOUTH	MCCLELLAN CREEK	1.3	2
THOMPSON RIVER SEC 01	Sanders	MEADOW CREEK - MOUTH	CLARK FORK RIVER	43.1	2
TIGER CREEK	Flathead	SOURCE - MOUTH	HUNGRY HORSE CREEK	6.4	2
TIMBER CREEK	Mineral	ABOUT 1 KM ABOVE RD CROSSING - FS PROPERTY BOUNDAR	ST REGIS RIVER	3.0	2
TIN CREEK	Flathead	SOURCE - MOUTH	S FK FLATHEAD RIVER	6.4	2
TINCUP CREEK	Ravalli	HEADWATERS - NATIONAL FOREST	BITTERROOT RIVER	21.4	2
TOBACCO RIVER	Lincoln	MOUTH OF SINCLAIR CREEK - LAKE KOOCANUSA AT FULL P	LAKE KOOCANUSA	7.4	2
TOBACCO RIVER	Lincoln	JUNCTION FORTINE & GRAVE CREEK - MOUTH OF ST CLAIR	LAKE KOOCANUSA	14.5	2
TOLAN CREEK	Ravalli	HEADWATERS - MOUTH	E FK BITTERROOT RIVER	13.3	2
TOSTON SPRINGS	Broadwater	SOURCE - MOUTH	MISSOURI RIVER SEC 11	7.0	2
TRAIL CREEK	Flathead	0.3 KM BELOW JEFF CREEK - MOUTH	STRAWBERRY CREEK	7.7	2
TRAPPER CREEK	Flathead	SOURCE - MOUTH	WHEELER CREEK	4.8	2
TRAPPER CREEK	Ravalli	HEADWATERS - MOUTH	W FK BITTERROOT RIVER	18.1	2
TROUT CREEK	Mineral	HEADWATERS - MOUTH	CLARK FORK RIVER	22.5	2
TUCHUCK CREEK	Flathead	HEADWATERS - MOUTH	TRAIL CREEK	6.5	2
TWENTYFIVE MILE CREEK	Flathead	EAR CREEK - 1 KM ABOVE MOOSE CREEK	M FK FLATHEAD RIVER	2.0	2
TWENTYFIVE MILE CREEK	Flathead	1 KM ABOVE MOUTH - MOUTH	M FK FLATHEAD RIVER	1.0	2
TWIN CREEK	Flathead	SOURCE - MOUTH	S FK FLATHEAD RIVER	24.1	2
W FK BITTERROOT RIVER	Ravalli	PAINTED ROCKS LAKE - MOUTH	BITTERROOT RIVER	31.5	2
W FK FISH CREEK	Mineral	HEADWATERS - MOUTH	FISH CREEK	20.9	2
W FK SCHAFER CREEK	Flathead	3.2 KM ABOVE MOUTH - MOUTH	SCHAFER CREEK	3.2	2
WALTON CREEK	Flathead	MOUTH OF CANYON AT KM 6.9 - 1ST TRIBUTARY ON N AT	LINCOLN CREEK	3.2	2
WARM SPRINGS CREEK	Deer Lodge	HEADWATERS - MOUTH	CLARK FORK RIVER	45.7	2
WARM SPRINGS CREEK	Ravalli	JCT HART CREEK TRAIL - MOUTH	E FK BITTERROOT RIVER	11.5	2
WARM SPRINGS CREEK	Powell	SOURCE - TRIB FROM E NEAR RIVER MILE 4	CLARK FORK RIVER	7.2	2
WATCHTOWER CREEK	Ravalli	HEADWATERS - MOUTH	NEZ PERCE FK BITTERROOT RIVER	12.5	2
WET COTTONWOOD CREEK	Powell	SOURCE - BLM BOUNDARY	COTTONWOOD CREEK	9.1	2
WHITCOMB CREEK	Flathead	SOURCE - MOUTH	SPOTTED BEAR RIVER	6.4	2
WHITE RIVER	Powell	SOURCE - NEEDLE FALLS	S FK FLATHEAD RIVER	20.9	2
WHITE RIVER	Powell	1.1 KM BELOW S FK WHITE RIVER - MOUTH	S FK FLATHEAD RIVER	8.8	2
WHITE RIVER	Powell	NEEDLE FALLS - 1.1 KM BELOW S FK WHITE RIVER	S FK FLATHEAD RIVER	4.8	2
WIGWAM CREEK	Lincoln	BLUEBIRD CREEK - STATE LINE	KOOTENAI RIVER	8.4	2
WILDCAT CREEK	Flathead	SOURCE - MOUTH	WOUNDED BUCK CREEK	6.4	2
WILLARD CREEK	Jefferson	0.8 KM ABOVE MOUTH - MOUTH	MCCLELLAN CREEK	0.8	2
WILLOW CREEK	Ravalli	NATIONAL FOREST - BN RAILROAD BRIDGE	BITTERROOT RIVER SEC 02	11.2	2
WILLOW CREEK	Ravalli	HEADWATERS - NATIONAL FOREST	BITTERROOT RIVER SEC 02	9.6	2
WILLOW SPRINGS	Madison	SOURCE - MOUTH	JEFFERSON RIVER	3.2	2
WOODS CREEK	Ravalli	HEADWATERS - MOUTH	W FK BITTERROOT RIVER	10.4	2

Montana Rivers Study
Rivers with Fisheries Value Class 2
Oil & Gas Region No. 1

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
WOUNDED BUCK CREEK	Flathead	3.5 KM ABOVE MOUTH - MOUTH	HUNGRY HORSE RESERVOIR	3.6	2
WOUNDED BUCK CREEK	Flathead	WILDCAT CREEK - 3.5 KM ABOVE MOUTH	HUNGRY HORSE RESERVOIR	1.2	2
WYMAN CREEK	Granite	MOOSE CREEK - MOUTH	ROCK CREEK	5.3	2
YAAK RIVER SEC 01	Lincoln	YAAK FALLS - MOUTH	KOOTENAI RIVER	14.4	2
YAKINIKAK CREEK	Flathead	NOKIO CREEK - TOP OF BIG BEAVER DAMS	TRAIL CREEK	3.6	2
YAKINIKAK CREEK	Flathead	0.1 KM ABOVE SEEMO CREEK - 0.1 KM ABOVE ANTLEY CRE	TRAIL CREEK	3.2	2
YOUNGS CREEK	Powell	FALLS - 5.8 KM ABOVE MOUTH	S FK FLATHEAD RIVER	13.0	2

Montana Rivers Study
Rivers with Fisheries Value Class 3
Oil & Gas Region No. 1

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
ADAIR CREEK	Park	BONHOMN RANCH XING - MOUTH	SHIELDS RIVER	6.0	3
AENEAS CREEK	Flathead	SOURCE - MOUTH	GRAVES CREEK	9.7	3
ALICE CREEK	Lewis & Clark	BEAR CREEK - MOUTH	BLACKFOOT RIVER	11.9	3
AMBROSE CREEK	Ravalli	HEADWATERS - FS GAUGING STATION	BITTERROOT RIVER SEC 01	8.9	3
ANDERSON CREEK	Park	HEADWATERS - MOUTH	MILL CREEK	2.6	3
ARMSTRONG SPRING CREEK	Park	ORIGIN - DEPUY'S DAM	YELLOWSTONE RIVER	1.1	3
ARRASTRA CREEK	Powell	NATIONAL FOREST RD 4106 - NATIONAL FOREST	BLACKFOOT RIVER	5.1	3
ASHLEY CREEK	Flathead	SMITH LAKE - AIRPORT RD	FLATHEAD RIVER	16.0	3
ASHLEY CREEK	Flathead	ASHLEY LAKE - SMITH LAKE	FLATHEAD RIVER	21.2	3
ASHLEY CREEK	Flathead	AIRPORT RD - MOUTH	FLATHEAD RIVER	27.7	3
BANGTAIL CREEK	Park	HEADWATERS - MOUTH	SHIELDS RIVER	16.4	3
BARR CREEK	Lewis & Clark	NEAR UPPER END - MOUTH	WILLOW CREEK	9.7	3
BARRON CREEK	Lincoln	6.3KM FROM MOUTH - MOUTH AT RESERVOIR	LAKE KOOCANUSA	6.3	3
BARTLETT CREEK	Powell	SOURCE - MOUTH	S FK FLATHEAD RIVER	11.3	3
BASIN CREEK	Flathead	HEADWATERS - 8.7 KM ABOVE BOWL CREEK	M FK FLATHEAD RIVER	1.8	3
BASS CREEK	Ravalli	HEADWATERS - NATIONAL FOREST	BITTERROOT RIVER	11.3	3
BEAR CREEK	Park	HEADWATERS - DARROCH CREEK	YELLOWSTONE RIVER	4.8	3
BEAR CREEK	Sanders	JCT SEC 2/3 - MOUTH	THOMPSON RIVER	6.4	3
BEAR CREEK	Deer Lodge	HEADWATERS - MOUTH	BIG HOLE RIVER SEC 02	10.1	3
BEAR CREEK	Flathead	5.9 KM ABOVE MOUTH - MOUTH	M FK FLATHEAD RIVER	5.9	3
BEAR CREEK	Flathead	0.8 KM ABOVE GIEFER CREEK - 5.9 KM ABOVE MOUTH	M FK FLATHEAD RIVER	7.7	3
BEAR CREEK	Flathead	1ST RR XING BELOW SUMMIT - 0.8 KM ABOVE GEIFER CRE	M FK FLATHEAD RIVER	10.1	3
BEAVER CREEK	Lewis & Clark	TOWN OF NELSON - MOUTH	MISSOURI RIVER	9.6	3
BEAVER CREEK	Lewis & Clark	HEADWATERS - NATIONAL FOREST	KEEP COOL CREEK	5.6	3
BEAVER CREEK	Missoula	7 KM ABOVE MOUTH - MOUTH	SWAN RIVER	7.0	3
BEAVER CREEK	Missoula	12.5 KM ABOVE MOUTH - 7 KM ABOVE MOUTH	SWAN RIVER	4.5	3
BEAVER CREEK	Missoula	SOURCE - 0.7 KM BELOW RD XING AT 13.3 K	SWAN RIVER	1.0	3
BEAVER CREEK	Lewis & Clark	HEADWATERS - TOWN OF NELSON	MISSOURI RIVER	16.0	3
BEAVERHEAD RIVER	Madison	ANDERSON LANE - MOUTH	JEFFERSON RIVER	45.7	3
BEAVERHEAD RIVER	Beaverhead	STODDEN DITCH - ANDERSON LANE	JEFFERSON RIVER	14.3	3
BEECHER CREEK	Missoula	W FK/E FK BEECHER CREEK - MOUTH	NINEMILE CREEK	2.1	3
BENT CREEK	Flathead	1.2 KM ABOVE MOUTH - MOUTH	SPOTTED BEAR RIVER	1.2	3
BENT CREEK	Flathead	0.3 KM BELOW RD #568 - 1.2 KM ABOVE MOUTH	SPOTTED BEAR RIVER	0.3	3
BENT CREEK	Flathead	1.6 KM ABOVE RD #2851 - 0.3 KM BELOW RD #568	SPOTTED BEAR RIVER	3.7	3
BIG CREEK	Park	SMOKEY CREEK - NATIONAL FOREST	YELLOWSTONE RIVER SEC 09	10.3	3
BIG CREEK	Ravalli	HEADWATERS - NATIONAL FOREST	BITTERROOT RIVER SEC 01	14.4	3
BIG SALMON RIVER	Flathead	PENDANT CREEK - SPUD CREEK	S FK FLATHEAD RIVER	10.1	3
BIG SHEEP CREEK	Beaverhead	SHEARING PEN GULCH - IRRIGATION DIVERSION	RED ROCK RIVER	11.9	3
BIRD CREEK	Missoula	HEADWATERS - MOUTH	NINEMILE CREEK	4.8	3
BLACK BEAR CREEK	Flathead	SOURCE - MOUTH	S FK FLATHEAD RIVER	11.3	3
BLACKFOOT RIVER SEC 03	Lewis & Clark	HEADWATERS - ARRASTRA CREEK	CLARK FORK RIVER	47.5	3
BLACKTAIL DEER CREEK	Beaverhead	EAST BENCH CANAL - MOUTH	BEAVERHEAD RIVER	3.7	3

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
BLACKTAIL DEER CREEK	Beaverhead	W FK BLACKTAIL CREEK - 2.4 KM ABOVE E BENCH CANAL	BEAVERHEAD RIVER	39.8	3
BLOODY DICK CREEK	Beaverhead	NATIONAL FOREST - MOUTH	HORSE PRAIRIE CREEK	17.1	3
BLOODY DICK CREEK	Beaverhead	PARK CREEK - NATIONAL FOREST	HORSE PRAIRIE CREEK	15.0	3
BLUESKY CREEK	Lincoln	TRAIL CROSSING 7.8KM FROM MOUT - JUNCTION WITH GRA	GRAVE CREEK	7.8	3
BOLES CREEK	Missoula	ELK MEADOW - MOUTH	PLACID CREEK	9.0	3
BOULDER CREEK	Granite	HEADWATERS - MOUTH	FLINT CREEK	17.7	3
BOULDER RIVER	Jefferson	COTTONWOOD CREEK - MOUTH	JEFFERSON RIVER	22.7	3
BOWL CREEK	Flathead	6.5 KM ABOVE BASIN CREEK - 0.1 KM ABOVE BASIN CREE	STRAWBERRY CREEK	6.4	3
BOZEMAN CREEK	Gallatin	MYSTIC LAKE - NATIONAL FOREST	E GALLATIN RIVER	13.7	3
BRACKETT CREEK	Gallatin	NATIONAL FOREST - MOUTH	SHIELDS RIVER	23.5	3
BRACKETT CREEK	Gallatin	N FK BRACKETT - NATIONAL FOREST	SHIELDS RIVER SEC 01	3.3	3
BRISTOW CREEK	Lincoln	4.9 KM FROM MOUTH - MOUTH AT RESERVOIR	LAKE KOOCANUSA	4.9	3
BRISTOW CREEK	Lincoln	JUNCTION OF N. S. FORKS - 4.9KM UP FROM RESERVOIR	LAKE KOOCANUSA	5.5	3
BROADWATER RIVER	Park	BROADWATER LAKE - MOUTH	CLARKS FORK YELLOWSTONE RIVER	7.2	3
BROCK CREEK	Powell	1 KM ABOVE FRONTAGE BRIDGE - FRONTAGE RD ABOVE I-9	CLARK FORK RIVER	1.0	3
BRUCE CREEK	Flathead	SOURCE - MOUTH	ADDITION CREEK	4.8	3
BUCK CREEK	Missoula	5 KM ABOVE MOUTH - 2 KM ABOVE MOUTH	SWAN RIVER	3.0	3
BULL RIVER	Sanders	BRIDGE - E FK BULL CREEK	CLARK FORK RIVER	12.9	3
BULL RIVER	Sanders	THREE FORKS - BRIDGE	CLARK FORK RIVER	10.8	3
BURNT FORK BITTERROOT RIVER	Ravalli	BURNT FORK LAKE - N & S BURNT FORK CREEK	BITTERROOT RIVER	7.9	3
BURNT FORK CREEK TRIB	Missoula	HEADWATERS - MOUTH	NINEMILE CREEK	2.3	3
BUSH CREEK	Ravalli	5560 FT ELEVATION - MOUTH	MARTIN CREEK	2.7	3
BUTLER CREEK	Missoula	HEADWATER - MOUTH	NINEMILE CREEK	11.3	3
BUTTE CABIN CREEK	Granite	AMMON GULCH - MOUTH	ROCK CREEK	4.8	3
CACHE CREEK	Mineral	FORKS - MOUTH	S FK FISH CREEK	20.9	3
CALF CREEK	Lewis & Clark	SOURCE - MOUTH	DANAHER CREEK	8.0	3
CAMERON CREEK	Ravalli	HEADWATERS - NATIONAL FOREST	E FK BITTERROOT RIVER	11.2	3
CAMP CREEK	Lincoln	SOURCE - MOUTH	LAKE CREEK	12.9	3
CAMP CREEK	Missoula	HEADWATERS - MOUTH	NINEMILE CREEK	5.6	3
CAMP CREEK	Ravalli	HEADWATERS - MOUTH	E FK BITTERROOT RIVER	18.2	3
CANYON CREEK	Lincoln	FALLS 1.5 MI UP MOUTH - MOUTH	LAKE KOOCANUSA	2.4	3
CANYON CREEK	Flathead	SOURCE - MOUTH	HUNGRY HORSE RESERVOIR	4.8	3
CANYON CREEK	Beaverhead	CANYON CREEK RANGER STATION - MOUTH	BIG HOLE RIVER	20.9	3
CANYON CREEK	Ravalli	HEADWATERS - NATIONAL FOREST	BITTERROOT RIVER SEC 02	8.8	3
CANYON CREEK	Flathead	2.2 KM ABOVE KIMMERLY CREEK - MOUTH	N FK FLATHEAD RIVER	2.2	3
CARIBOU CREEK	Lincoln	HEADWATERS - MOUTH	E FK YAAK RIVER	10.0	3
CARLTON CREEK	Missoula	HEADWATERS - NATIONAL FOREST	BITTERROOT RIVER SEC 01	8.0	3
CEDAR CREEK	Lincoln	CEDAR LAKES - MOUTH	KOOTENAI RIVER	10.5	3
CEDAR CREEK	Lake	9.5 KM ABOVE MOUTH - MOUTH	SWAN RIVER	9.5	3
CEDAR CREEK	Lake	LAKE AT KM 14.6 - 9.5 KM ABOVE MOUTH	SWAN RIVER	5.1	3
CEDAR LOG CREEK	Mineral	HEADWATERS - MOUTH	W FK FISH CREEK	16.0	3
CHARLIE CREEK	Flathead	HEADWATERS - 5.6 KM ABOVE MOUTH	M FK FLATHEAD RIVER	2.0	3

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
CHARLIE CREEK	Flathead	2.8 KM ABOVE MOUTH - MOUTH	M FK FLATHEAD RIVER	2.9	3
CILLY CREEK	Lake	2 KM ABOVE MOUTH - MOUTH	SWAN RIVER	2.0	3
CLARENCE CREEK	Lincoln	1KM PAST END OF CLARENCE ROAD - GRAVES CREEK	GRAVE CREEK	6.2	3
CLARK CANYON RES SPRINGS	Beaverhead	SOURCE - MOUTH	RED ROCK RIVER	4.0	3
CLARK FORK RIVER SEC 01	Sanders	THOMPSON FALLS DAM - HWY 10A BRIDGE	COLUMBIA RIVER	6.4	3
CLARK FORK RIVER SEC 01	Sanders	FLATHEAD RIVER - THOMPSON FALLS RESERVOIR	COLUMBIA RIVER	56.3	3
CLARK FORK RIVER SEC 01	Sanders	SIEGEL CREEK - FLATHEAD RIVER	COLUMBIA RIVER	8.0	3
CLARK FORK RIVER SEC 03	Granite	BEARMOUTH BRIDGE - ROCK CREEK	PEND OREILLE RIVER	31.7	3
CLARK FORK RIVER SEC 03	Granite	LITTLE BLACKFOOT RIVER - BEARMOUTH BRIDGE	PEND OREILLE RIVER	57.0	3
CLARK FORK RIVER SEC 04	Deer Lodge	DEMPSEY CREEK - LITTLE BLACKFOOT RIVER	PEND OREILLE RIVER	39.9	3
CLARKS FORK YELLOWSTONE SEC 03	Park	LADY OF THE LAKE CREEK - STATE LINE	YELLOWSTONE RIVER	5.0	3
CLAYTON CREEK	Flathead	CLAYTON LAKE - HUNGRY HORSE RESERVOIR	S FK FLATHEAD RIVER	8.0	3
CLEARWATER RIVER	Missoula	LAKE INEZ - MOUTH	BLACKFOOT RIVER	27.0	3
COKE CREEK	Park	COKEDALE - MOUTH	BILLMAN CREEK	4.8	3
COLD CREEK	Missoula	SOURCE - BRIDGE AT KM 8.0	SWAN RIVER	9.0	3
CONDON CREEK	Lake	BRIDGE AT 9 KM - 6 KM ABOVE MOUTH	SWAN RIVER	3.0	3
COPPER CREEK	Lewis & Clark	RED CREEK - MOUTH	LANDERS FORK BLACKFOOT RIVER	18.7	3
COPPER CREEK	Granite	6280 FT ELEVATION/BEGIN STEEP - MOUTH	BOULDER CREEK	0.8	3
COPPER CREEK	Granite	6320 FT ELEVATION/BELOW BRIDGE - 6280 FT ELEVATION	BOULDER CREEK	0.8	3
COPPER CREEK	Granite	6520 FT ELEVATION - END OF SWAMP ABOVE RD XING	BOULDER CREEK	2.7	3
COTTONWOOD CREEK	Missoula	COTTONWOOD LAKES - MOUTH	BLACKFOOT RIVER	19.3	3
COTTONWOOD CREEK	Powell	N & M FK - MOUTH	CLARK FORK RIVER	14.5	3
COTTONWOOD CREEK	Madison	CONFLUENCE OF TRIBS - CENTER SEC 19	RUBY RIVER	3.4	3
COUGAR CREEK	Gallatin	PARK - MOUTH	DUCK CREEK	3.2	3
COUGAR CREEK	Granite	HEADWATERS - MOUTH	ROCK CREEK SEC 02	5.3	3
CRIPPLE HORSE CREEK	Lincoln	CONFLUENCE S. FORK CRIPPLE HOR - LAKE KOOCANUSA AT	LAKE KOOCANUSA	3.6	3
CROW CREEK	Sanders	SOURCE - MOUTH	PROSPECT CREEK	1.6	3
CROW CREEK	Broadwater	HALL CREEK - NATIONAL FOREST	MISSOURI RIVER	8.9	3
CROW CREEK	Broadwater	NATIONAL FOREST - RADERSBURG	MISSOURI RIVER	9.0	3
DAISY CREEK	Missoula	SOURCE - MOUTH	W FK GOLD CREEK	6.4	3
DANAHER CREEK	Powell	HEADWATERS - RAPID CREEK	S FK FLATHEAD RIVER	13.7	3
DANAHER CREEK	Flathead	6.8 KM ABOVE MOUTH - MOUTH	S FK FLATHEAD RIVER	6.8	3
DARLINGTON DITCH	Gallatin	UPPER END FISH ACCESS SITE - LOWER END FISH ACCESS	MADISON	3.6	3
DEADMAN CREEK	Beaverhead	SOURCE - MOUTH	BIG SHEEP CREEK	27.2	3
DEARBORN RIVER	Lewis & Clark	NATIONAL FOREST - MOUTH	MISSOURI RIVER	75.6	3
DEARBORN RIVER	Lewis & Clark	NEAR HEADWATERS - NATIONAL FOREST	MISSOURI RIVER	22.8	3
DEEP CREEK	Sanders	SOURCE - MOUTH	CLARK FORK RIVER	8.0	3
DEEP CREEK	Deer Lodge	FRENCH CREEK - MOUTH	BIG HOLE RIVER	2.4	3
DEEP CREEK	Broadwater	HEADWATERS - NATIONAL FOREST	MISSOURI RIVER	15.4	3
DEEP CREEK	Lincoln	6KM ABOVE MOUTH - JUNCTION WITH FORTINE CREEK	FORTINE CREEK	5.8	3
DEEP CREEK	Lincoln	BRIDGE 12 KM UP FROM MOUTH - 6KM ABOVE MOUTH	FORTINE CREEK	6.1	3
DEEP CREEK	Deer Lodge	HEADWATERS - FRENCH CREEK	BIG HOLE RIVER	6.4	3

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
DEER CREEK	Mineral	CRONIE CREEK - MOUTH	ST REGIS RIVER	4.5	3
DEERLICK CREEK	Flathead	1.6 KM ABOVE HWY XING - MOUTH	M FK FLATHEAD RIVER	4.4	3
DEVILS CREEK	Missoula	HEADWATERS - MOUTH	NINEMILE CREEK	5.4	3
DIVIDE CREEK	Silver Bow	E FK DIVIDE CREEK - MOUTH	BIG HOLE RIVER	18.5	3
DOG CREEK	Powell	BLOSSBURG - MOUTH	LITTLE BLACKFOOT RIVER	9.7	3
DONALDSON CREEK	Lake	SOURCE - MOUTH	LAKE MARY RONAN	1.6	3
DRY CREEK	Park	HEADWATERS - MOUTH	YELLOWSTONE RIVER	8.0	3
DRY CREEK	Broadwater	SOURCE - NATIONAL FOREST	MISSOURI RIVER	11.3	3
DUCK CREEK	Gallatin	YELLOWSTNE PARK LINE - MOUTH	HEBGEN LAKE	5.0	3
E BR S FK BIG CREEK	Lincoln	5.4KM UP EAST WEST JUNCTION - EAST WEST BRANCH JUN	SOUTH FORK BIG CREEK	5.4	3
E BR S FK BIG CREEK	Lincoln	9.6KM UP EAST WEST JUNCTION - 5.4KM JUNCTION EAST	SOUTH FORK BIG CREEK	4.1	3
E FK BLACKTAIL DEER CREEK	Beaverhead	NATIONAL FOREST - MOUTH	BLACKTAIL DEER CREEK	26.2	3
E FK BURNT FORK CREEK	Missoula	HEADWATERS - MOUTH	BURNT FORK CREEK	3.8	3
E FK MCCLELLAN CREEK	Jefferson	4.5 KM ABOVE MOUTH - MOUTH	MCCLELLAN CREEK	4.5	3
E FK MILL CREEK	Park	UPPER SAGE CREEK - SAGE CREEK	MILL CREEK	1.0	3
E FK PIPE CREEK	Lincoln	E BOUNDARY SEC 3 - 11 KM BELOW BEARFITE CREEK	PIPE CREEK	1.6	3
E FK PIPE CREEK	Lincoln	TRIB/E BANK - E BOUNDARY SEC 3	PIPE CREEK	2.0	3
E FK ROCK CREEK	Park	HEADWATERS - MOUTH	ROCK CREEK	3.2	3
E FK ROCK CREEK	Sanders	ROCK LAKE - MOUTH	ROCK CREEK	10.0	3
EAST GALLATIN RIVER	Gallatin	HYALITE CREEK - SMITH CREEK	GALLATIN RIVER	16.3	3
EAST GALLATIN RIVER	Gallatin	SMITH CREEK - MOUTH	GALLATIN RIVER	19.8	3
EIGHTMILE CREEK	Ravalli	HEADWATERS - NORTH FORK	BITTERROOT RIVER SEC 01	8.0	3
ELDRIDGE CREEK	Park	HEADWATERS - MOUTH	COKE CREEK	4.8	3
ELK CREEK	Lewis & Clark	NATIONAL FOREST - MOUTH	SUN RIVER	36.8	3
ELK CREEK	Park	N & S FK ELK CREEK - MOUTH	SHIELDS RIVER	9.5	3
ELK CREEK	Sanders	E & W FK ELK CREEK - MOUTH	CLARK FORK RIVER	9.3	3
ELK CREEK	Flathead	1 KM ABOVE MOUTH - MOUTH	DIRTYFACE CREEK	1.0	3
ELKHORN CREEK	Lewis & Clark	HEADWATERS - MOUTH	WILLOW CREEK	11.3	3
ESSEX CREEK	Flathead	MARION CREEK - RR XING	M FK FLATHEAD RIVER	1.9	3
FINLEY CREEK	Missoula	HEADWATERS - MOUTH	PLACID CREEK	5.5	3
FISHTRAP CREEK	Sanders	BEARTRAP FORK - MOUTH	THOMPSON RIVER	20.0	3
FISHTRAP CREEK	Deer Lodge	E FK FISHTRAP CREEK - MOUTH	BIG HOLE RIVER	4.0	3
FIVEMILE CREEK	Lincoln	JUNCTION OF S.FORK - LAKE KOOCANUSA AT FULL POOL	LAKE KOOCANUSA	10.6	3
FLAT CREEK	Mineral	HEADWATERS AT SPRING - MOUTH	CLARK FORK RIVER	12.8	3
FLATHEAD CREEK	Gallatin	N FK FLATHEAD CREEK - MOUTH	SHIELDS RIVER	19.2	3
FLATHEAD RIVER SEC 01	Sanders	INDIAN RESERVATION - MOUTH	CLARK FORK RIVER	6.4	3
FLINT CREEK SEC 01	Granite	PHILLIPSBURG - MOUTH	CLARK FORK RIVER	42.0	3
FLINT CREEK SEC 01	Granite	GEORGETOWN LAKE - PHILLIPSBURG	CLARK FORK RIVER	17.5	3
FORTINE CREEK	Lincoln	SWAMP CREEK - MOUTH	TOBACCO RIVER	27.6	3
FORTINE CREEK	Lincoln	UPPER END OF TWIN MEADOWS - MOUTH OF SWAMP CREEK	TOBACCO RIVER	11.9	3
FOUR LAKES CREEK	Sanders	N FK FOUR LAKES RD XING - MOUTH	W FK THOMPSON RIVER	2.7	3
FOUR LAKES CREEK	Sanders	UPPER FORKS - N FK RD XING	W FK THOMPSON RIVER	2.1	3

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
FOURTH-OF-JULY CREEK	Lincoln	BRAMLET CREEK - MOUTH	WEST FISHER RIVER	2.9	3
FRAZER CREEK	Missoula	HEADWATERS - MOUTH	RATTLESNAKE CREEK	5.7	3
FRED BURR CREEK	Ravalli	HEADWATERS - NATIONAL FOREST	BITTERROOT RIVER SEC 02	16.0	3
FREELAND CREEK	Lake	SOURCE - MOUTH	LAKE MARY RONAN	1.6	3
GALLATIN RIVER SEC 02	Gallatin	CAMERON BRIDGE - BAKER CREEK	MISSOURI RIVER	11.6	3
GATES CREEK	Lewis & Clark	NEAR UPPER END - MOUTH	N FK SUN RIVER	6.8	3
GEIFER CREEK	Flathead	SNAKE CREEK - MOUTH	BEAR CREEK	3.7	3
GIBSON SPRING CREEK	Gallatin	SOURCE - MOUTH	EAST GALLATIN RIVER	3.1	3
GLACIER CREEK	Missoula	BOTTOM OF GLACIER SLOUGHS - 11 KM ABOVE MOUTH	SWAN RIVER	4.3	3
GLACIER CREEK	Missoula	GLACIER LAKE - CRAZY HORSE CREEK	SWAN RIVER	1.5	3
GOLD CREEK	Powell	CREVICE CREEK - MOUTH	CLARK FORK RIVER	10.1	3
GOLDIE CREEK	Flathead	1.5 KM ABOVE MOUTH - MOUTH	HUNGRY HORSE RESERVOIR	1.5	3
GOOD CREEK	Lincoln	5.3 KM ABOVE MOUTH - MOUTH	BIG CREEK	5.3	3
GORDON CREEK	Powell	11.9 KM ABOVE MOUTH - MOUTH	S FK FLATHEAD RIVER	11.9	3
GORDON CREEK	Powell	SHAW CREEK - 1.3 KM ABOVE CARDINAL CREEK	S FK FLATHEAD RIVER	4.7	3
GORDON CREEK	Powell	DOCTOR CREEK - SHAW CREEK	S FK FLATHEAD RIVER	2.6	3
GORGE CREEK	Flathead	SUNBURST LAKE FORK - MOUTH	BUNKER CREEK	12.9	3
GRANITE CREEK	Lincoln	GRANITE LAKE - MOUTH	BIG CHERRY CREEK	14.7	3
GRAVE CREEK	Lincoln	IRRIGATION DIVERSION - JUNCTION WITH FORTINE CREEK	TOBACCO RIVER	6.9	3
GRAVE CREEK	Lincoln	MOUTH OF BLUE SKY CREEK - IRRIGATION DIVERSION	TOBACCO RIVER	30.4	3
GRAVE CREEK	Lincoln	MOUTH OF FOUNDATION CREEK - MOUTH OF BLUE SKY CR	TOBACCO RIVER	6.2	3
GRAVES CREEK	Flathead	SOURCE - MOUTH	HUNGRY HORSE RESERVOIR	14.5	3
GRAVES CREEK	Sanders	SOURCE - MOUTH	CLARK FORK RIVER	12.9	3
GRAYLING CREEK	Gallatin	PARK - MOUTH	HEBGEN LAKE	7.4	3
GREEN CANYON CREEK	Gallatin	HEADWATERS - MOUTH	FLATHEAD CREEK	4.8	3
GROOM CREEK	Lake	SOURCE - 3 KM ABOVE MOUTH	SWAN LAKE	3.0	3
GURNETT CREEK	Broadwater	HEADWATERS - TRIB FROM EAST	CANYON FERRY RESERVOIR	6.8	3
HALL CREEK	Lake	2 KM ABOVE MOUTH - MOUTH	SWAN LAKE	2.0	3
HAMMOND CREEK	Park	HEADWATERS - MOUTH	ROCK CREEK	6.4	3
HARRIS CREEK	Flathead	SOURCE - MOUTH	HUNGRY HORSE RESERVOIR	4.8	3
HARRIS CREEK	Madison	HEADWATERS - MOUTH	CALIFORNIA CREEK	6.4	3
HEMLOCK CREEK	Missoula	SOURCE - MOUTH	KRAFT CREEK	6.0	3
HERRIG CREEK	Flathead	LAKE AT SOURCE - LITTLE BITTERROOT LAKE	LITTLE BITTERROOT RIVER	9.7	3
HOKE CREEK	Flathead	1.9 KM ABOVE MOUTH - MOUTH	HUNGRY HORSE RESERVOIR	1.9	3
HOLBROOK CREEK	Powell	SOURCE - MOUTH	S FK FLATHEAD RIVER	12.9	3
HOLLAND CREEK	Missoula	FALLS - HOLLAND LAKE	SWAN RIVER	0.8	3
HOLLOMAN CREEK	Missoula	450 M ABOVE PRIVATE LAND - PRIVATE LAND	MILLER CREEK	0.5	3
HOPE CREEK	Lewis & Clark	BEAVER PONDS - MOUTH	DOG CREEK	2.6	3
HORSE CREEK	Park	HEADWATERS - MOUTH	TOM MINER CREEK	12.9	3
HORSE CREEK	Park	NATIONAL FOREST - MOUTH	SHIELDS RIVER	19.5	3
HORSE PRAIRIE CREEK	Beaverhead	BLOODY DICK CREEK - CLARK CANYON RESERVOIR	BEAVERHEAD RIVER	29.0	3
HYALITE CREEK SEC 01	Gallatin	HYLITE RESERVOIR - NATIONAL FOREST	GALLATIN RIVER	14.6	3

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
JACK CREEK	Madison	LEVI CREEK - NATIONAL FOREST	MADISON RIVER	5.6	3
JIM CREEK	Missoula	ABOVE BRIDGE AT 2 KM - MOUTH	SWAN RIVER	2.0	3
JIM CREEK	Lake	9.5 KM ABOVE MOUTH - 5.5 KM ABOVE MOUTH	SWAN RIVER	4.0	3
JOHNSON CREEK	Beaverhead	SOURCE - MOUTH	N FK BIG HOLE RIVER	22.5	3
JONES CREEK	Beaverhead	RD END 2.4 KM ABOVE - RD XING AT WOLFE CORRALS	MUD CREEK	2.4	3
JONES CREEK	Beaverhead	280 M UP RIGHT FK ABOVE FORKS - RD END/CONIFER EDG	MUD CREEK	1.2	3
JOSEPH CREEK	Beaverhead	ANDERSON CREEK - MOUTH	TRAIL CREEK	10.0	3
KAY CREEK	Park	HEADWATERS - MOUTH	SHIELDS RIVER	5.6	3
KEELER CREEK	Lincoln	SOURCE - MOUTH	LAKE CREEK	30.4	3
KLEINSCHMIDT CREEK	Powell	SOURCE - MOUTH	N FK BLACKFOOT RIVER	4.7	3
KLETOMUS CREEK	Flathead	MOOSE LAKE - MOUTH	HALLOWAT CREEK	5.6	3
KRAFT CREEK	Missoula	7 KM ABOVE MOUTH - 3 KM ABOVE MOUTH	GLACIER CREEK	4.0	3
LACY CREEK	Beaverhead	HEADWATERS - MOUTH	WISE RIVER	11.9	3
LAKE CREEK	Missoula	HEADWATERS - MOUTH	RATTLESNAKE CREEK	3.5	3
LAKE CREEK	Flathead	SCOTT LAKE - 2.5 KM ABOVE MOUTH	M FK FLATHEAD RIVER	4.9	3
LAKE CREEK	Lincoln	MT POWER & LIGHT DAM - MOUTH	KOOTENAI RIVER	2.0	3
LAKE CREEK	Lincoln	SOURCE-BULL LAKE - MT POWER & LIGHT DAM	KOOTENAI RIVER	30.0	3
LAMARCHE CREEK	Deer Lodge	W FK LA MARCHE - NATIONAL FOREST	BIG HOLE RIVER	12.9	3
LAMARCHE CREEK	Deer Lodge	FS BOUNDARY - MOUTH	BIG HOLE RIVER SEC 02	4.8	3
LANDERS FORK BLACKFOOT R	Lewis & Clark	SOURCE - FALLS CREEK	BLACKFOOT RIVER	26.4	3
LANDERS FORK BLACKFOOT RIVER	Lewis & Clark	FALLS CREEK - MOUTH	BLACKFOOT RIVER	18.0	3
LEWIS CREEK	Lincoln	2.8KM FROM MOUTH - GRAVES CREEK	GRAVES CREEK	2.8	3
LIMESTONE CREEK	Lewis & Clark	SOURCE - MOUTH	DANAHER CREEK	8.0	3
LINCOLN CREEK	Flathead	WALTON CREEK - MOUTH	M FK FLATHEAD RIVER	8.0	3
LION CREEK	Lake	19.6 KM ABOVE MOUTH - 10 KM ABOVE MOUTH	SWAN RIVER	9.5	3
LITTLE BLACKFOOT R SEC 01	Powell	ELLISTON - MOUTH	CLARK FORK RIVER	37.2	3
LITTLE BLACKFOOT R SEC 02	Powell	HEADWATERS - ELLISTON	CLARK FORK RIVER	30.4	3
LITTLE BOULDER CREEK	Ravalli	HEADWATERS - PAINTED ROCKS LAKE	W FK BITTERROOT RIVER	7.2	3
LITTLE JOE CREEK	Mineral	N & S FK LITTLE JOE CREEK - MOUTH	ST REGIS RIVER	3.7	3
LITTLE LAKE CREEK	Beaverhead	HEADWATERS - NATIONAL FOREST	BIG HOLE RIVER	8.5	3
LITTLE THOMPSON RIVER	Sanders	HEADWATERS - MOUTH	THOMPSON RIVER	23.8	3
LOGAN CREEK	Flathead	TALLY LAKE - MOUTH	STILLWATER RIVER	12.4	3
LOGAN CREEK	Lincoln	STATE LINE - MOUTH	STAR CREEK	3.2	3
LOGAN CREEK	Flathead	SOURCE - MOUTH	HUNGRY HORSE RESERVOIR	6.4	3
LONG CREEK	Beaverhead	NATIONAL FOREST - MOUTH	RED ROCK RIVER	16.8	3
LOOKOUT CREEK	Lincoln	SOURCE - MOUTH	S FK BIG CREEK	6.4	3
LOST CREEK	Deer Lodge	HEADWATERS - NATIONAL FOREST	CLARK FORK RIVER	11.3	3
LOST CREEK	Lake	2.3 KM ABOVE MOUTH - MOUTH	SWAN RIVER	2.3	3
LOST HORSE CREEK	Ravalli	SOURCE - MOUTH	BITTERROOT RIVER	36.0	3
LOWER TWIN CREEK	Flathead	SOURCE - 9.4 KM ABOVE MOUTH	S FK FLATHEAD RIVER	6.7	3
LOWER TWIN CREEK	Flathead	4.5 KM ABOVE MOUTH - MOUTH	S FK FLATHEAD RIVER	4.5	3
LOWER TWIN CREEK	Flathead	9.4 KM ABOVE MOUTH - 4.5 KM ABOVE MOUTH	S FK FLATHEAD RIVER	4.9	3

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
LOWER WILLOW CREEK	Granite	WILLOW CREEK RESERVOIR - MOUTH	FLINT CREEK	11.5	3
M FK BULL RIVER	Sanders	SOURCE - MOUTH	BULL RIVER	8.5	3
MARSH SPRING CREEK	Broadwater	SOURCE - MOUTH	WARM SPRINGS CREEK	4.8	3
MCCLAIN CREEK	Missoula	HEADWATERS - NATIONAL FOREST	SQUAW CREEK	4.0	3
MCCLELLAN CREEK	Jefferson	E FK MCCLELLAN CREEK - NATIONAL FOREST	PRICKLY PEAR CREEK	2.8	3
MCDERMOTT CREEK	Powell	HEADWATERS - MOUTH	COOPERS LAKE	3.5	3
MCDONALD CREEK	Flathead	LAKE MCDONALD OUTLET - MOUTH	M FK FLATHEAD RIVER	3.2	3
MCINERNIE CREEK	Flathead	SOURCE - 2.2 KM ABOVE MOUTH	HUNGRY HORSE RESERVOIR	2.6	3
MCINERNIE CREEK	Flathead	2.2 KM ABOVE MOUTH - 1.2 KM ABOVE MOUTH	HUNGRY HORSE RESERVOIR	1.0	3
MCINERNIE CREEK	Flathead	1.2 KM ABOVE MOUTH - MOUTH	HUNGRY HORSE RESERVOIR	1.2	3
MCKAY CREEK	Sanders	SOURCE - IMPROVED ROAD END	NOXON RAPIDS RESERVOIR	3.8	3
MCMANUS CREEK	Mineral	BELOW ROAD CROSSING - MOUTH	ST REGIS RIVER	3.7	3
MCNINCH CREEK	Beaverhead	SW 1/4 SEC 18 - MOUTH	MUDDY CREEK	0.8	3
MEADOW CREEK	Park	HEADWATERS - MOUTH	SMITH CREEK	5.6	3
MEADOW CREEK	Lincoln	N & S FK - MOUTH	YAAK RIVER	1.6	3
MEADOW CREEK	Lewis & Clark	HEADWATERS - MOUTH	E FK N FK BLACKFOOT RIVER	6.8	3
MEDICINE LODGE CREEK	Beaverhead	AYERS CANYON - IRRIGATION DIVERSION	HORSE PRAIRIE CREEK	28.2	3
MILES CREEK	Park	HEADWATERS - MOUTH	BRACKETT CREEK	11.3	3
MILL CREEK	Deer Lodge	HEADWATERS - MOUTH	SILVER BOW CREEK	29.0	3
MISSION CREEK	Park	NATIONAL FOREST - MOUTH	YELLOWSTONE RIVER	17.2	3
MISSOURI RIVER SEC 12	Broadwater	THREE FORKS - TOSTON DAM	MISSISSIPPI RIVER	41.4	3
MOL HERON CREEK	Park	DEAF JIM CREEK - CINNABAR CREEK	YELLOWSTONE RIVER SEC 09	5.0	3
MONTANA CREEK	Mineral	HEADWATERS - MOUTH	CACHE CREEK	8.0	3
MOOSE CREEK	Silver Bow	NATIONAL FOREST - MOUTH	BIG HOLE RIVER	23.2	3
MORMON CREEK	Missoula	5320 FT ELEVATION - NATIONAL FOREST	LOLO CREEK	5.6	3
MORRELL CREEK	Missoula	MORRELL LAKE - MOUTH	CLEARWATER RIVER	19.3	3
MURRAY CREEK	Flathead	SOURCE - MOUTH	HUNGRY HORSE RESERVOIR	4.8	3
N FK BIG CREEK	Lincoln	.06KM UP FROM MESLER CREEK - NORTH AND SOUTH FORK	BIG CREEK	5.2	3
N FK BIG CREEK	Lincoln	8.7 KM ABOVE N/S FK JUNCTION - 0.06 KM ABOVE MESLE	BIG CREEK	3.5	3
N FK BRACKETT CREEK	Gallatin	HEADWATERS - MOUTH	BRACKETT CREEK	3.6	3
N FK BRISTOW CREEK	Lincoln	1.7KM UP FROM S.FORK BRISTOW C - JUNCTION OF N S F	BRISTOW CREEK	1.7	3
N FK BULL RIVER	Sanders	HEADWATERS - MOUTH	BULL RIVER	8.0	3
N FK COLD CREEK	Missoula	HEADWATERS - MOUTH	COLD CREEK	5.3	3
N FK ELK CREEK	Missoula	1.5 KM ABOVE MOUTH - MOUTH	ELK CREEK	1.5	3
N FK KEELER CREEK	Lincoln	BRIDGE XING - MOUTH	KEELER CREEK	6.7	3
N FK LOST CREEK	Lake	7.3 KM ABOVE MOUTH - MOUTH	LOST CREEK	7.3	3
N FK LOST CREEK	Lake	11.4 KM ABOVE MOUTH - 7.3 KM ABOVE MOUTH	LOST CREEK	4.2	3
N FK MEADOW CREEK	Lincoln	HEADWATERS - MOUTH	MEADOW CREEK	7.4	3
N FK O'BRIEN CREEK	Lincoln	SOURCE - MOUTH	O'BRIAN CREEK	9.7	3
N FK SUN RIVER	Lewis & Clark	NEAR UPPER END - MOUTH	SUN RIVER	42.5	3
NICOLA CREEK	Flathead	FISH BARRIER - MOUTH	BIG CREEK	1.1	3
NOISY CREEK	Flathead	SOURCE - MOUTH	ECHO CREEK	3.2	3

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
NORTH MEADOW CREEK	Madison	SURESHOT LAKES FORK - NATIONAL FOREST	ENNIS LAKE	3.4	3
NORTH MEADOW CREEK	Madison	NATIONAL FOREST - MOUTH	ENNIS LAKE	16.3	3
NORTH WILLOW CREEK	Madison	CATARACT CREEK - MOUTH	WILLOW CREEK	17.4	3
NORWEGIAN CREEK	Madison	NATIONAL FOREST - MOUTH	WILLOW CREEK RESERVOIR	14.5	3
NYACK CREEK	Flathead	FALLS AT KM 13.4 - 11.4 KM ABOVE MOUTH	M FK FLATHEAD RIVER	1.9	3
O'BRIEN CREEK	Lincoln	N FK O'BRIEN CREEK - MOUTH	KOOTENAI RIVER	14.6	3
ODELL CREEK	Beaverhead	0.6 KM ABOVE MOUTH - MOUTH	WYMAN CREEK	0.6	3
ODELL CREEK	Beaverhead	3.8 KM ABOVE MOUTH - 0.6 KM ABOVE MOUTH	WYMAN CREEK	3.2	3
ODELL CREEK	Beaverhead	7.2 KM ABOVE MOUTH - 3.8 KM ABOVE MOUTH	WYMAN CREEK	3.4	3
ODELL CREEK	Beaverhead	ODELL LAKE - 7.2 KM ABOVE MOUTH	WYMAN CREEK	1.4	3
ONEHORSE CREEK	Ravalli	HEADWATERS - NATIONAL FOREST	BITTERROOT RIVER SEC 01	8.0	3
OWL CREEK	Missoula	PLACID LAKE - MOUTH	CLEARWATER RIVER	5.5	3
PACKER CREEK	Mineral	300 M BELOW TRAIL CROSSING - BORDER PRIVATE	ST REGIS RIVER	3.2	3
PAINT CREEK	Flathead	1.5 KM ABOVE MOUTH - MOUTH	HUNGRY HORSE RESERVOIR	1.5	3
PAINT CREEK	Flathead	SOURCE - 1.5 KM ABOVE MOUTH	HUNGRY HORSE RESERVOIR	2.4	3
PAOLA CREEK	Flathead	STEEP GRADIENT - PAOLA CREEK RD CULVERT	M FK FLATHEAD RIVER	3.3	3
PARSON'S SLOUGH	Madison	SOURCE - MOUTH	JEFFERSON RIVER	6.2	3
PATTENGAIL CREEK	Beaverhead	HEADWATERS - MOUTH	WISE RIVER	23.0	3
PETE CREEK	Lincoln	PETE CREEK CABIN - MOUTH	YAAK RIVER	14.7	3
PETERSON CREEK	Powell	HEADWATERS - GULLY ON APPLEGATE RANCH	CLARK FORK RIVER	9.6	3
PILGRIM CREEK	Sanders	SOURCE - MOUTH	CLARK FORK RIVER	13.4	3
PINE CREEK	Park	NATIONAL FOREST - MOUTH	YELLOWSTONE RIVER SEC 09	4.8	3
PINE CREEK	Park	S FK PINE CREEK - NATIONAL FOREST	YELLOWSTONE RIVER SEC 09	6.1	3
PINKHAM CREEK	Lincoln	FALLS (6 MI) - MOUTH	KOOTENAI RIVER	9.7	3
PINTLAR CREEK	Beaverhead	NATIONAL FOREST - MOUTH	BIG HOLE RIVER	19.2	3
PIONEER CREEK	Beaverhead	HEADWATERS - MOUTH	RUBY CREEK	4.8	3
PIPE CREEK	Lincoln	NOISY CREEK - MOUTH	KOOTENAI RIVER	25.3	3
PIPE CREEK	Lincoln	HEADWATERS - NOISY CREEK	KOOTENAI RIVER	18.7	3
PIPER CREEK	Lake	2 KM ABOVE MOUTH - MOUTH	SWAN RIVER	2.0	3
PLACID CREEK	Missoula	N FK PLACID CREEK - MOUTH	PLACID LAKE	13.8	3
PONY CREEK	Lake	6.8 KM ABOVE MOUTH - 2.9 KM ABOVE MOUTH	SWAN RIVER	3.9	3
PONY CREEK	Lake	SOURCE - 6.8 KM ABOVE MOUTH	SWAN RIVER	2.3	3
POORMAN CREEK	Lewis & Clark	FIELDS GULCH - MOUTH	BLACKFOOT RIVER	9.3	3
POORMAN CREEK	Lewis & Clark	FORKS - FIELDS GULCH	BLACKFOOT RIVER	10.8	3
PORCUPINE CREEK	Missoula	HEADWATERS - MOUTH	RATTLESNAKE CREEK	5.6	3
PRICKLY PEAR CREEK	Lewis & Clark	NATIONAL FOREST - CLANCY CREEK	LAKE HELENA	16.6	3
PRICKLY PEAR CREEK	Lewis & Clark	CLANCY CREEK - COUNTY RD XING	LAKE HELENA	21.8	3
PROSPECT CREEK	Sanders	SOURCE - MOUTH	CLARK FORK RIVER	27.5	3
RAND CREEK	Flathead	SOURCE - MOUTH	ASHLEY LAKE	6.4	3
RATTLESNAKE CREEK	Beaverhead	MCMANNIS CREEK - ERMONT GULCH	BEAVERHEAD RIVER	29.9	3
RATTLESNAKE CREEK	Missoula	PILCHER CREEK - MOUNTAIN WATER CO DAM	CLARK FORK RIVER SEC 03	7.6	3
RATTLESNAKE CREEK	Missoula	3000 FEET BELOW BEESKOVE CREEK - 2000 FEET ABOVE P	CLARK FORK RIVER SEC 03	1.2	3

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
RATTLESNAKE CREEK	Missoula	3000 FEET ABOVE BEESKOVE CREEK - BEESKOVE CREEK	CLARK FORK RIVER SEC 03	0.6	3
RATTLESNAKE CREEK	Missoula	FRANKLIN BRIDGE - 3000 FEET ABOVE BEESKOVE CREEK	CLARK FORK RIVER SEC 03	2.0	3
RATTLESNAKE CREEK	Missoula	2000 FEET BELOW HIGH FALLS CR - FRANKLIN BRIDGE	CLARK FORK RIVER SEC 03	2.9	3
RATTLESNAKE CREEK	Missoula	HIGH FALLS CREEK - 2000 FEET BELOW HIGH FALLS CR	CLARK FORK RIVER SEC 03	0.6	3
RATTLESNAKE CREEK	Missoula	WRANGLE CREEK - HIGH FALLS CREEK	CLARK FORK RIVER SEC 03	6.9	3
RATTLESNAKE CREEK	Missoula	HEADWATERS - WRANGLE CREEK	CLARK FORK RIVER SEC 03	9.4	3
RED ROCK CREEK	Beaverhead	UPPER RED ROCK LAKE - LOWER RED ROCK LAKE	RED ROCK RIVER	11.5	3
RED ROCK RIVER SEC 01	Beaverhead	LIMA RESERVOIR - BIG SHEEP CREEK	BEAVERHEAD RIVER	34.0	3
RIVERSIDE CREEK	Flathead	SOURCE - FOREST ROUTE 38 CULVERT	S FK FLATHEAD RIVER	4.7	3
ROARING LION CREEK	Ravalli	HEADWATERS - NATIONAL FOREST	BITTERROOT RIVER SEC 02	16.0	3
ROCK CREEK	Park	SMELLER CREEK - NATIONAL FOREST	SHIELDS RIVER	3.7	3
ROCK CREEK	Lewis & Clark	NEAR UPPER END - TWO MILES ABOVE MOUTH	N FK SUN RIVER	8.0	3
ROCK CREEK	Ravalli	HEADWATERS - LAKE COMO	BITTERROOT RIVER SEC 02	16.8	3
ROCK CREEK	Sanders	JUNCTION E & W FORKS - MOUTH	CABINET GORGE RESERVOIR	10.0	3
ROSS CREEK	Lincoln	S FK - FALLS	BULL LAKE	7.2	3
RUBY CREEK	Beaverhead	HEADWATERS - BUTLER CREEK	S FK TRAIL CREEK	17.9	3
RUBY CREEK	Madison	1 MI ABOVE BEARTRAP CREEK - MOUTH	MADISON RIVER	10.6	3
RUBY RIVER SEC 02	Madison	NATIONAL FOREST - RUBY RIVER RESERVOIR	BEAVERHEAD RIVER	35.3	3
RUBY RIVER SEC 02	Madison	WARM SPRINGS CREEK - NATIONAL FOREST	BEAVERHEAD RIVER	9.7	3
S FK BIG CREEK	Lincoln	MOUTH OF DROP CREEK - NORTH SOUTH FORK BIG JUNCTIO	BIG CREEK	12.0	3
S FK BIG CREEK	Lincoln	JUNCT.EAST WEST BRANCH SOUTH F - MOUTH OF DROP CRE	BIG CREEK	12.1	3
S FK BULL RIVER	Sanders	SOURCE - MOUTH	BULL RIVER	7.4	3
S FK ELK CREEK	Park	HEADWATERS - MOUTH	ELK CREEK	12.9	3
S FK KEELER CREEK	Lincoln	HEADWATERS - MOUTH	KEELER CREEK	5.8	3
S FK LITTLE JOE CREEK	Mineral	SUNSET CREEK - MOUTH	LITTLE JOE CREEK	8.7	3
S FK LOGAN CREEK	Flathead	SOURCE - MOUTH	HUNGRY HORSE RESERVOIR	5.6	3
S FK LOST CREEK	Lake	0.2 KM BELOW CLIFF CREEK - 0.5 KM ABOVE BRIDGE AT	LOST CREEK	7.0	3
S FK LOST CREEK	Lake	3 KM ABOVE MOUTH - MOUTH	LOST CREEK	3.0	3
S FK MADISON RIVER	Gallatin	HEADWATERS - RR LINE	MADISON RIVER	11.7	3
S FK MEADOW CREEK	Lincoln	HEADWATERS - MOUTH	MEADOW CREEK	7.4	3
S FK RED MEADOW CREEK	Flathead	SOURCE - MOUTH	RED MEADOW CREEK	8.0	3
S FK SUN RIVER	Lewis & Clark	HOADLEY CREEK - MOUTH	SUN RIVER	25.1	3
S FK YAAK RIVER	Lincoln	ZULU CREEK - MOUTH	YAAK RIVER	11.9	3
S FK YOUNG CREEK	Lincoln	2.3 KM ABOVE MOUTH - MOUTH	YOUNG CREEK	2.3	3
SAVENAC CREEK	Mineral	NATIONAL FOREST - MOUTH	ST REGIS RIVER	3.0	3
SAVENAC CREEK	Mineral	200 M ABOVE SECTION BOUNDARY - 400 M BELOW END OF	ST REGIS RIVER	2.5	3
SAVENAC CREEK	Mineral	400 M BELOW TRIBUTARY FORKS - 200 M ABOVE SEC BOUN	ST REGIS RIVER	2.4	3
SAVENAC CREEK	Mineral	UPPER TRIBUTARY - 400 M BELOW TRIBUTARY FORKS	ST REGIS RIVER	0.9	3
SAVENAC CREEK	Mineral	1200 M ABOVE TRIBUTARY FORK - UPPER TRIBUTARY	ST REGIS RIVER	1.1	3
SCHAFER CREEK	Flathead	HEADWATERS - 0.4 KM BELOW W FK	M FK FLATHEAD RIVER	3.7	3
SCHWARTZ CREEK	Missoula	HEADWATERS - MOUTH	CLARK FORK RIVER	5.6	3
SEYMOUR CREEK	Deer Lodge	ARCOLA BOY SCOUT CAM - MOUTH	BIG HOLE RIVER	12.9	3

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
SHAW CREEK	Powell	SOURCE - MOUTH	GORDON CREEK	5.6	3
SHIELDS RIVER SEC 01	Park	CLYDE PARK - MOUTH	YELLOWSTONE RIVER	25.4	3
SHIELDS RIVER SEC 02	Park	WILSALL - CLYDE PARK	YELLOWSTONE RIVER	21.6	3
SHIELDS RIVER SEC 03	Park	HEADWATERS - WILSALL	YELLOWSTONE RIVER	45.9	3
SILVER BUTTE CREEK	Lincoln	HEADWATERS - MOUTH	EAST FISHER CREEK	12.6	3
SILVER CREEK	Lewis & Clark	BELOW MARYSVILLE - NEAR SILVER CITY	MISSOURI RIVER	3.4	3
SILVER SPRING	Madison	SOURCE - MOUTH	RUBY RIVER	1.4	3
SILVERTIP CREEK	Flathead	SOURCE - MOUTH	SPOTTED BEAR RIVER	16.1	3
SINCLAIR CREEK	Lincoln	BUILDINGS 10.2KM FROM MOUTH - JUNCTION WITH TOBACC	TOBACCO RIVER	10.2	3
SIX MILE CREEK TRIB	Missoula	HEADWATERS - MOUTH	SIXMILE CREEK	3.5	3
SIXMILE CREEK	Park	NATIONAL FOREST - GOLDRUN CREEK	YELLOWSTONE RIVER	3.4	3
SIXMILE CREEK	Park	BIG PINE CREEK - NATIONAL FOREST	YELLOWSTONE RIVER	4.7	3
SIXMILE CREEK	Lake	SOURCE - MOUTH	SWAN LAKE	6.0	3
SIXMILE CREEK TRIB	Missoula	HEADWATERS - MOUTH	SIXMILE CREEK	3.4	3
SIXTEENMILE CREEK	Gallatin	HEADWATERS - HIGGINS RESERVOIR	MISSOURI RIVER	31.9	3
SIXTEENMILE CREEK	Gallatin	HIGGINS RESERVOIR - SIXTEEN	MISSOURI RIVER	21.8	3
SIXTEENMILE CREEK	Gallatin	SIXTEEN - MAUDLOW	MISSOURI RIVER	22.5	3
SIXTEENMILE CREEK	Gallatin	MAUDLOW - MOUTH	MISSOURI RIVER	23.2	3
SKALKAHO CREEK	Ravalli	HEADWATERS - NATIONAL FOREST	BITTERROOT RIVER	22.5	3
SLOUGH CREEK	Park	WOUNDED MAN CREEK - PARK BOUNDARY	LAMAR RIVER	16.4	3
SMITH CREEK	Park	NATIONAL FOREST - MOUTH	SHIELDS RIVER	4.0	3
SODA SPRINGS CREEK	Ravalli	HEADWATERS - MOUTH	LITTLE W FK NEZ PERCE FK BIT R	10.7	3
SOLDIER CREEK	Missoula	1 MI E OF BURNT FORK PINNACLE - MOUTH	NINEMILE CREEK	8.0	3
SOUP CREEK	Lake	12.3 KM ABOVE MOUTH - MOUTH OF CANYON AT KM 10.2	SWAN RIVER	2.1	3
SOUTH BOULDER CREEK	Granite	FS RD #1503 XING - FS RD #1503 XING	BOULDER CREEK	1.0	3
SOUTH BOULDER RIVER	Madison	NATIONAL FOREST - HWY 359 BRIDGE	JEFFERSON RIVER	10.8	3
SOUTH BOULDER RIVER	Madison	HEADWATERS - NATIONAL FOREST	JEFFERSON RIVER	11.1	3
SOUTH LOST HORSE CREEK	Ravalli	ABOVE FALLS - MOUTH	LOST HORSE CREEK	0.8	3
SOUTH LOST HORSE CREEK	Ravalli	WILDERNESS BOUNDARY - GORGE	LOST HORSE CREEK	2.4	3
SOUTH MEADOW CREEK	Madison	SOUTH MEADOW CREEK LAKE - NATIONAL FOREST	ENNIS LAKE	6.4	3
SOUTH WILLOW CREEK	Madison	POTOSI RANGER STATN - MOUTH	WILLOW CREEK	22.4	3
SOUTH WOODWARD CREEK	Lake	5 KM ABOVE MOUTH - 2 KM ABOVE MOUTH	WOODWARD CREEK	3.0	3
SPOKANE CREEK	Lewis & Clark	1.6 KM ABOVE MOUTH - MOUTH	HAUSER RESERVOIR	1.6	3
SPREAD CREEK	Lincoln	HIDDEN CREEK - MOUTH	YAAK RIVER	16.0	3
SPRING BRANCH CREEK	Gallatin	SOURCE - MOUTH	EAST GALLATIN RIVER	6.2	3
SPRING CREEK	Flathead	HEADWATERS - MOUTH	STILLWATER RIVER	8.5	3
SPRING GULCH	Missoula	HEADWATERS - MOUTH	RATTLESNAKE CREEK	9.3	3
ST LOUIS CREEK	Missoula	HEADWATERS - MOUTH	NINEMILE CREEK	3.7	3
STEEP CREEK	Lincoln	1.6KM ABOVE MOUTH - MOUTH OF STEEP CREEK	BIG CREEK	1.6	3
STICKNEY CREEK	Lewis & Clark	N & S FK - MOUTH	MISSOURI RIVER	6.1	3
STILLWATER RIVER	Flathead	LOWER STILLWATER LAKE - SPENCER LAKE OUTLET	FLATHEAD RIVER	21.9	3
STILLWATER RIVER	Flathead	HWY 93 BRIDGE - LOWER STILLWATER LAKE	FLATHEAD RIVER	15.1	3

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
STILLWATER RIVER	Lincoln	HEADWATERS - HWY 93 BRIDGE	FLATHEAD RIVER	17.4	3
STONY CREEK	Missoula	HEADWATERS - MOUTH	NINEMILE CREEK	8.0	3
STORY CREEK	Gallatin	COUNTY RD - MOUTH	E GALLATIN RIVER	6.0	3
SULLIVAN CREEK	Lincoln	MOUTH OF BURRD CREEK - MOUTH OF SULLIVAN CREEK	LAKE KOOCANUSA	5.2	3
SUN RIVER SEC 02	Lewis & Clark	NATIONAL FOREST - ELK CREEK	MISSOURI RIVER	47.9	3
SUN RIVER SEC 02	Lewis & Clark	GIBSON DAM - NATIONAL FOREST	MISSOURI RIVER	4.8	3
SUNDAY CREEK	Flathead	HEADWATERS - MOUTH	STILLWATER RIVER	14.5	3
SWAMP CREEK	Sanders	WANLESS LAKES - END OF RD	CLARK FORK RIVER	12.4	3
SWAN RIVER SEC 01	Flathead	SWAN LAKE - FLATHEAD LAKE	FLATHEAD RIVER	22.9	3
SWEENEY CREEK	Ravalli	HEADWATERS - NATIONAL FOREST	BITTERROOT RIVER SEC 01	14.4	3
SWIFT CREEK	Flathead	W FK SWIFT CREEK - WHITEFISH LAKE	WHITEFISH RIVER	29.0	3
TAMARACK CREEK	Mineral	FORK - DRY FORK	CLARK FORK	6.2	3
TAYLOR FORK GALLATIN RIVER	Gallatin	LIGHTENING CREEK - MOUTH	GALLATIN RIVER	18.2	3
TAYLOR FORK GALLATIN RIVER	Gallatin	SOURCE - LIGHTENING CREEK	GALLATIN RIVER	8.4	3
TEEPEE CREEK	Flathead	TEEPEE LAKE - MOUTH	N FK FLATHEAD RIVER	4.8	3
TEEPEE CREEK	Flathead	HEADWATERS - TEEPEE LAKE	N FK FLATHEAD RIVER	12.8	3
TELEGRAPH CREEK	Powell	CLEAR CUT HEAD OF CANYON - BRYAN CREEK	LITTLE BLACKFOOT RIVER	1.3	3
TENT CREEK	Flathead	SOURCE - MOUTH AT HUNGRY HORSE RESRVOIR	HUNGRY HORSE RESERVOIR	4.0	3
THERRIAULT CREEK	Lincoln	3 KM ABOVE HWY 93 BRIDGE - TOBACCO RIVER	TOBACCO RIVER	4.4	3
THOMPSON CREEK	Gallatin	HEADWATERS - EAST/WEST COUNTY RD	E GALLATIN RIVER	1.9	3
THOMPSON RIVER SEC 01	Sanders	INDIAN CREEK - MEADOW CREEK	CLARK FORK RIVER	8.9	3
THOMPSON RIVER SEC 02	Flathead	LOWER THOMPSON LAKE - INDIAN CREEK	CLARK FORK RIVER	16.1	3
THREEMILE CREEK	Ravalli	HEADWATERS - BITTERROOT GAME RANGE	BITTERROOT RIVER SEC 01	8.7	3
TIZER CREEK	Jefferson	LOWER TIZER LAKE - LITTLE TIZER CREEK	CROW CREEK	8.2	3
TOM CREEK	Beaverhead	HEADWATERS - MOUTH	UPPER RED ROCK LAKE	8.0	3
TRAIL CREEK	Beaverhead	HOGAN CREEK - MOUTH	N FK BIG HOLE RIVER	27.4	3
TRAIL CREEK	Flathead	HEADWATERS - 0.3 KM BELOW JEFF CREEK	M FK FLATHEAD RIVER	4.0	3
TROUT CREEK	Lewis & Clark	FORKS - MOUTH	HAUSER LAKE	11.3	3
TROUT CREEK	Madison	0.8 KM ABOVE OLD CABIN - MOUTH MAJOR DRAINAGE FROM	BEAVERHEAD RIVER	1.6	3
TWELVEMILE CREEK	Mineral	FLAT ROCK BRIDGE - MOUTH	ST REGIS RIVER	5.7	3
TWELVEMILE CREEK	Mineral	HEADWATERS - FLAT ROCK BRIDGE	ST REGIS RIVER	11.0	3
TWENTYFIVE MILE CREEK	Flathead	1 KM ABOVE MOOSE CREEK - 1 KM ABOVE MOUTH	M FK FLATHEAD RIVER	5.4	3
TWO BEAR CREEK	Ravalli	1712 M ELEVATION - MOUTH	SLEEPING CHILD CREEK	5.2	3
TYLER CREEK	Granite	BELOW TALUS SLOPE - GATE ACROSS RD SEC 23/26	CLARK FORK RIVER	0.9	3
UPPER WILLOW CREEK	Granite	SOURCE - NATIONAL FOREST	ROCK CREEK	8.0	3
URVI CREEK	Lewis & Clark	HEADWATERS - MOUTH	TENDERFOOT CREEK	2.1	3
VERMILION RIVER	Sanders	VERMILION FALLS - MOUTH	CLARK FORK RIVER	18.0	3
W BR S FK BIG CREEK	Lincoln	4KM FROM EAST BRANCH JUNCTION - EAST WEST BRANCH J	SOUTH FORK BIG CREEK	4.0	3
W FK BEECHER CREEK	Missoula	HEADWATERS - MOUTH	BEECHER CREEK	3.3	3
W FK BITTERROOT RIVER	Ravalli	HEADWATERS - PAINTED ROCKS LAKE	BITTERROOT RIVER	34.8	3
W FK BUTTE CREEK	Missoula	HEADWATERS - NAT FOREST 1.1 KM ABOVE MOUTH	S FK LOLO CREEK	9.4	3
W FK MADISON RIVER	Madison	SOAP CREEK - MOUTH	MADISON RIVER	4.0	3

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
W FK MADISON RIVER	Madison	MERIDIAN CREEK - SOAP CREEK	MADISON RIVER	12.4	3
W FK PACKER CREEK	Mineral	800 M BELOW TRIBUTARY FORKS - NATIONAL FOREST	PACKER CREEK	3.7	3
W FK QUARTZ CREEK	Lincoln	JCT SEC 19/20 - MOUTH	QUARTZ CREEK	8.0	3
W FK S FK SUN RIVER	Lewis & Clark	AHORN CREEK - MOUTH	S FK SUN RIVER	12.4	3
W FK THOMPSON RIVER	Sanders	HEADWATERS - MOUTH	THOMPSON RIVER	12.9	3
W FK YAAK RIVER	Lincoln	STATE LINE - MOUTH	YAAK RIVER	13.5	3
W FK YAAK RIVER	Lincoln	WINKUM CREEK - STATE LINE	YAAK RIVER	8.8	3
WALL CREEK	Flathead	SOURCE - MOUTH	SPOTTED BEAR RIVER	9.7	3
WALTON CREEK	Flathead	1ST TRIBUTARY ON N AT KM 3.7 - MOUTH	LINCOLN CREEK	3.7	3
WARD CREEK	Mineral	SOURCE - MOUTH	ST REGIS RIVER	11.9	3
WARLAND CREEK	Lincoln	7.6KM UP FROM MOUTH - MOUTH OF WARLAND AT FULL POO	LAKE KOOCANUSA	7.6	3
WARM SPRINGS CREEK	Beaverhead	LITTLE MILK CREEK - NATIONAL FOREST	BIG HOLE RIVER	6.6	3
WARM SPRINGS CREEK	Beaverhead	NATIONAL FOREST - MOUTH	BIG HOLE RIVER	16.1	3
WARM SPRINGS CREEK	Madison	STILL CREEK - MOUTH	RUBY RIVER	6.0	3
WARM SPRINGS CREEK	Beaverhead	HEADWATERS - RD	RUBY RIVER	2.4	3
WARM SPRINGS CREEK	Broadwater	SOURCE (PLUNKET LAKE) - MOUTH	MISSOURI RIVER SEC 11	14.5	3
WEASEL CREEK	Lincoln	SOURCE - STATE LINE	WIGWAM RIVER	6.4	3
WEEKSVILLE CREEK	Sanders	HEADWATERS - MOUTH	CLARK FORK RIVER	9.7	3
WEST BOULDER RIVER	Park	NATIONAL FOREST - MOUTH	BOULDER RIVER	22.9	3
WEST BOULDER RIVER	Park	HEADWATERS - NATIONAL FOREST	BOULDER RIVER	19.5	3
WEST FISHER CREEK	Lincoln	STANDARD CREEK - MOUTH	FISHER RIVER	19.3	3
WEST ROSEBUD CREEK	Park	HEADWATERS - ISLAND LAKE OUTLET	ROSEBUD CREEK	12.7	3
WHEELER CREEK	Flathead	1.7 KM ABOVE MOUTH - MOUTH	HUNGRY HORSE RESERVOIR	1.7	3
WHEELER CREEK	Flathead	10.0 KM ABOVE MOUTH - 1.7 KM ABOVE MOUTH	HUNGRY HORSE RESERVOIR	8.3	3
WHISTLER CREEK	Flathead	HEADWATERS - MOUTH	LODGEPOLE CREEK	3.1	3
WHITE CREEK	Mineral	HEADWATERS - MOUTH	CACHE CREEK	6.4	3
WHITEFISH RIVER	Flathead	ROSE XING BRIDGE - MOUTH	STILLWATER RIVER	8.4	3
WHITEFISH RIVER	Flathead	HODGSON RD BRIDGE - ROSE XING BRIDGE	STILLWATER RIVER	15.3	3
WILLOW CREEK	Lewis & Clark	NATIONAL FOREST - MOUTH	HOLTER RESERVOIR	4.0	3
WILLOW CREEK	Lewis & Clark	NATIONAL FOREST - MOUTH	BLACKFOOT RIVER	8.0	3
WILLOW CREEK	Deer Lodge	GORGE CREEK - NATIONAL FOREST	BIG HOLE RIVER	19.2	3
WILLOW CREEK	Gallatin	N & S WILLOW CREEK - WILLOW CREEK RESERVOIR	JEFFERSON RIVER	11.1	3
WILLOW CREEK	Gallatin	WILLOW CREEK DAM - MOUTH	JEFFERSON RIVER	17.7	3
WISE RIVER	Beaverhead	LACY CREEK - MOUTH	BIG HOLE RIVER	33.3	3
WISE RIVER	Beaverhead	SOURCE/JACOBSON & MONO CREEKS - LACY CREEK	BIG HOLE RIVER	11.4	3
WOLF CREEK	Lewis & Clark	NEAR FORKS - MOUTH	LITTLE PRICKLY PEAR CREEK	14.8	3
WOLF CREEK	Lincoln	HEADWATERS - LITTLE WOLF CREEK	FISHER RIVER	33.8	3
WOODWARD CREEK	Lake	3.5 KM ABOVE MOUTH - MOUTH	SWAN RIVER	3.5	3
WOUNDED BUCK CREEK	Flathead	SOURCE - 2.3 KM ABOVE WILDCAT CREEK	HUNGRY HORSE RESERVOIR	0.9	3
WOUNDED BUCK CREEK	Flathead	2.3 KM ABOVE WILDCAT CREEK - WILDCAT CREEK	HUNGRY HORSE RESERVOIR	2.3	3
WRANGLE CREEK	Missoula	HEADWATERS - MOUTH	RATTLESNAKE CREEK	9.0	3
YAKINIKAK CREEK	Flathead	HEAD WATERS - NOKIO CREEK	TRAIL CREEK	2.7	3

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
YAKINIKAK CREEK	Flathead	TOP OF BIG BEAVER DAMS - 0.1 KM ABOVE SEEMO CREEK	TRAIL CREEK	3.3	3
YAKINIKAK CREEK	Flathead	0.1 KM ABOVE ANTLEY CREEK - BOTTOM OF DRY SECTION	TRAIL CREEK	3.0	3
YELLOW BAY CREEK	Lake	SOURCE - MOUTH	FLATHEAD LAKE	6.4	3
YEW CREEK	Lake	SOURCE - MOUTH	SWAN RIVER	2.2	3
YOUNG CREEK	Lincoln	0.3 KM N OF ALKALI LAKE - MOUTH AT KOOCANUSA AT FU	LAKE KOOCANUSA	3.1	3
YOUNG CREEK	Lincoln	2.5 KM UPSTREAM AMISH MEADOW - .3 KM NE OF ALKALI	LAKE KOOCANUSA	2.8	3
YOUNG CREEK	Lincoln	JUNCTION S FORK YOUNG CREEK - 3KM FROM AMISH MEADO	LAKE KOOCANUSA	6.8	3
YOUNG CREEK	Lincoln	3.1 KM FROM SOUTH FORK JUNCTIO - SOUTH AND MAIN FO	LAKE KOOCANUSA	3.1	3
YOUNGS CREEK	Powell	5.8 KM ABOVE MOUTH - MOUTH	S FK FLATHEAD RIVER	5.8	3

Montana Rivers Study
Rivers with Fisheries Value Class 1
Oil & Gas Region No. 2

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
LEE CREEK	Pondera	HEADWATERS - MOUTH	NORTH BADGER CREEK	3.2	1
MILK RIVER SEC 01	Valley	PORCUPINE CREEK - MOUTH	MISSOURI RIVER	13.0	1
MILK RIVER SEC 01	Valley	HINSDALE - PORCUPINE CREEK	MISSOURI RIVER	152.0	1
MISSOURI RIVER SEC 01	Valley	MILK RIVER - BIG MUDDY CREEK	MISSISSIPPI RIVER	176.2	1
MISSOURI RIVER SEC 01	Valley	BIG MUDDY CREEK - STATE LINE	MISSISSIPPI RIVER	88.0	1
MISSOURI RIVER SEC 05	Valley	FT PECK DAM - MILK RIVER	MISSISSIPPI RIVER	13.7	1
MISSOURI RIVER SEC 06A	Blaine	BLAINE/CHOTEAU COUNTY BY - FT PECK RESERVOIR	MISSISSIPPI RIVER	125.7	1
MISSOURI RIVER SEC 06B	Blaine	MARIAS RIVER - BLAINE/CHOUTEAU CO LINE	MISSISSIPPI RIVER	134.7	1
MISSOURI RIVER SEC 07	Cascade	MARONY DAM - MARIAS RIVER	MISSISSIPPI RIVER	77.2	1
MISSOURI RIVER SEC 09	Cascade	SHEEP CREEK - CASCADE BRIDGE	MISSISSIPPI RIVER	19.8	1
MISSOURI RIVER SEC 09	Cascade	HOLTER DAM - DEARBORN RIVER	MISSISSIPPI RIVER	22.2	1
MISSOURI RIVER SEC 09	Cascade	DEARBORN RIVER - SHEEP CREEK	MISSISSIPPI RIVER	16.4	1
N FK DEEP CREEK	Cascade	HEADWATERS - MOUTH	SMITH RIVER	7.2	1
NORTH BADGER CREEK	Pondera	NEAR UPPER END - FALLS	BIG BADGER CREEK	9.8	1

Montana Rivers Study
Rivers with Fisheries Value Class 2
Oil & Gas Region No. 2

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
CHAMBERLAIN CREEK	Cascade	4 KM ABOVE MOUTH - MOUTH	JEFFERSON CREEK	4.0	2
COW CREEK	Teton	NEAR UPPER END - MOUTH	BLACKLEAF CREEK	4.8	2
DEEP CREEK	Cascade	FORKS - DEVILS CANYON	SMITH RIVER	5.0	2
MARIAS RIVER SEC 01	Chouteau	TIBER DAM - MOUTH	MISSOURI RIVER	128.0	2
MILK RIVER SEC 02	Phillips	MALTA - HINSDALE	MISSOURI RIVER	165.6	2
MILK RIVER SEC 03	Phillips	HWY 2 BRIDGE - MALTA	MISSOURI RIVER	82.8	2
MILK RIVER SEC 03	Blaine	HAVRE WATER WEIR - FT BELKNAP INDIAN RESERVATION	MISSOURI RIVER	107.9	2
MILK RIVER SEC 03	Blaine	FT BELKNAP INDIAN RESERVATION - HWY 2 BRIDGE/INDIA	MISSOURI RIVER	107.8	2
MISSOURI RIVER SEC 08	Cascade	CASCADE BRIDGE - SMITH RIVER	MISSISSIPPI RIVER	42.8	2
N FK DEEP CREEK	Teton	NEAR UPPER END - NATIONAL FOREST	DEEP CREEK	3.2	2
N FK LITTLE BADGER CREEK	Glacier	NEAR UPPER END - BLACKFEET INDIAN RESERVATION	TWO MEDICINE RIVER	2.1	2
N FK LITTLE BELT CREEK	Cascade	HEADWATERS - NATIONAL FOREST	LITTLE BELT CREEK	3.0	2
PILGRIM CREEK	Cascade	FORKS - MOUTH	BELT CREEK	12.7	2
S FK DUPUYER CREEK	Teton	HEADWATERS - NATIONAL FOREST	DUPUYER CREEK	4.3	2
S FK TWO MEDICINE RIVER	Glacier	HEADWATERS - PIKE CREEK	TWO MEDICINE RIVER	15.0	2
SCOFFIN CREEK	Pondera	HEADWATERS - MOUTH	DUPUYER CREEK	11.3	2
TETON RIVER SEC 01	Teton	CHOTEAU - HWY 221	MARIAS RIVER	16.1	2
W FK POPLAR RIVER	Valley	STATE LINE - FT PECK INDIAN RESERVATION	POPLAR RIVER	95.6	2

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
BADGER CABIN CREEK	Pondera	BADGER CABIN - MOUTH	N FK BADGER CREEK	1.6	3
BADGER CREEK	Pondera	N & S FK - BLACKFEET INDIAN RESERVATION	TWO MEDICINE RIVER	12.1	3
BATTLE CREEK	Blaine	STATE LINE - MOUTH	MILK RIVER	96.0	3
BEAVER CREEK	Phillips	SEVENMILE CREEK - MOUTH	MILK RIVER	120.0	3
BEAVER CREEK SEC 01	Hill	BEAVER CREEK RESERVOIR DAM - MOUTH	MILK RIVER	27.3	3
BEAVER CREEK SEC 03	Hill	ROCKY BOY INDIAN RESERVATION - BEARPAW LAKE	MILK RIVER	24.5	3
BELT CREEK	Cascade	RICEVILLE BRIDGE - BIG WILLOW CREEK	MISSOURI RIVER	43.1	3
BELT CREEK	Cascade	JEFFERSON CREEK - 0.5 KM BELOW DRY FORK	MISSOURI RIVER	26.5	3
BELT CREEK	Cascade	0.5 KM BELOW DRY FK - RICEVILLE BRIDGE	MISSOURI RIVER	23.8	3
BENSON CREEK	Pondera	HEADWATERS - MOUTH	S FK TWO MEDICINE RIVER	3.2	3
BIG SANDY CREEK	Hill	CHOUTEAU COUNTY LINE - MOUTH	MILK RIVER	62.0	3
BOX CREEK	Glacier	ONE MILE ABOVE MOUTH - MOUTH	S FK TWO MEDICINE RIVER	1.6	3
CHERRY CREEK	Valley	SHIPP RANCH - MOUTH	MILK RIVER	32.0	3
CRAWFORD CREEK	Cascade	FOREST BOUNDARY - MOUTH	BELT CREEK	4.0	3
CUT BANK CREEK SEC 01	Glacier	INDIAN RESERVATION - 1 MI ABOVE SPRING CREEK	MARIAS RIVER	8.7	3
CUT BANK CREEK SEC 01	Glacier	1 MI ABOVE SPRING CREEK - MOUTH	MARIAS RIVER	17.7	3
DEARBORN RIVER	Cascade	NATIONAL FOREST - MOUTH	MISSOURI RIVER	75.6	3
DEEP CREEK	Cascade	DEVILS CANYON - MOUTH	SMITH RIVER	9.6	3
DEER CREEK	Cascade	CENTER OF SECTION 33 - MOUTH	PILGRIM CREEK	1.0	3
DRY FORK BELT CREEK	Cascade	NEAR UPPER END - GALENA CREEK	BELT CREEK	5.6	3
FOURCHETTE CREEK	Phillips	9 MI ABOVE MOUTH - MOUTH	FT PECK RESERVOIR	14.5	3
FRENCHMAN CREEK	Phillips	STATE LINE - MOUTH	MILK RIVER	120.0	3
HIGHWOOD CREEK	Cascade	NATIONAL FOREST - SHEPARD XING	MISSOURI RIVER	30.6	3
HIGHWOOD CREEK	Chouteau	CHOUTEAU COUNTY LINE - NATIONAL FOREST	MISSOURI RIVER	9.2	3
HOUND CREEK	Cascade	FORKS - MOUTH	SMITH RIVER	45.7	3
JAMES CREEK	Cascade	SECTION 5/6 BOUNDARY - MOUTH	TILLINGHAST CREEK	2.0	3
JEFFERSON CREEK	Cascade	FORKS - MOUTH	BELT CREEK	5.5	3
LITTLE BELT CREEK	Cascade	MAIN AND BALDY CREEKS - MOUTH	BELT CREEK	21.9	3
LODGE CREEK	Blaine	STATE LINE - MOUTH	MILK RIVER	120.0	3
LOST SHIRT CREEK	Pondera	HEADWATERS - MOUTH	S FK TWO MEDICINE RIVER	3.2	3
M FK LITTLE BELT CREEK	Cascade	NEAR HEADWATERS - MOUTH	LITTLE BELT CREEK	3.0	3
MARIAS RIVER SEC 02	Pondera	CUT BANK CREEK - TIBER RESERVOIR	MISSOURI RIVER	64.4	3
MILK RIVER SEC 04	Hill	FRESNO DAM - HAVRE WATER WEIR	MISSOURI RIVER	19.3	3
MILK RIVER SEC 05	Hill	INTERNATIONAL BOUNDARY - FRESNO RESERVOIR	MISSOURI RIVER	43.3	3
MISSOURI RIVER SEC 08	Cascade	SAND COULEE CREEK - BLACK EAGLE DAM	MISSISSIPPI RIVER	14.2	3
MISSOURI RIVER SEC 08	Cascade	SMITH RIVER - SAND COULEE CREEK	MISSISSIPPI RIVER	39.9	3
MISSOURI RIVER SEC 08	Cascade	BLACK EAGLE DAM - MARONY DAM	MISSISSIPPI RIVER	13.6	3
N FK DUPUYER CREEK	Teton	HEADWATERS - NATIONAL FOREST	DUPUYER CREEK	4.8	3
N FK LITTLE BELT CREEK	Cascade	NATIONAL FOREST - MOUTH	LITTLE BELT CREEK	3.5	3
N FK SUN RIVER	Teton	NEAR UPPER END - MOUTH	SUN RIVER	42.5	3
NORTH BADGER CREEK	Pondera	FALLS - MOUTH	BADGER CREEK	1.0	3
PORCUPINE CREEK	Valley	W & M FK - MOUTH	MILK RIVER	64.0	3

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
RAFFERTY CREEK	Cascade	FOREST BOUNDARY - MOUTH	BELT CREEK	5.0	3
REDROCK COULEE	Blaine	RD XING N OF LOHMAN - MOUTH	MILK RIVER	23.0	3
ROCK CREEK	Valley	STATE LINE - MOUTH	MILK RIVER	120.0	3
S FK BIRCH CREEK	Pondera	NEAR UPPER END - BIRCH CREEK RESERVOIR	BIRCH CREEK	11.4	3
S FK DEEP CREEK	Cascade	HEADWATERS - MOUTH	SMITH RIVER	6.8	3
S FK SMITH RIVER	Cascade	HUSSEY CREEK - MOUTH	SMITH RIVER	24.0	3
SHEEP CREEK	Pondera	NATIONAL FOREST - MOUTH	DUPUYER CREEK	34.3	3
SHEEP CREEK	Cascade	FORKS - MOUTH	MISSOURI RIVER	3.2	3
SHONKIN CREEK	Chouteau	NATIONAL FOREST - TOWN OF SHONKIN	MISSOURI RIVER	19.3	3
SIDNEY CREEK	Pondera	HEADWATERS - MOUTH	S FK TWO MEDICINE RIVER	3.2	3
SMITH RIVER SEC 01	Cascade	HOUND CREEK - TRULY BRIDGE	MISSOURI RIVER	21.2	3
SMITH RIVER SEC 02	Cascade	ROCK CREEK - CANYON	MISSOURI RIVER	73.9	3
SNAKE CREEK	Blaine	BEAN CREEK - MOUTH	MILK RIVER	56.0	3
SOUTH BADGER CREEK	Pondera	NEAR UPPER END - MOUTH	BIG BADGER CREEK	6.4	3
SPRING CREEK	Teton	NEAR UPPER END - MOUTH	TETON RIVER	15.4	3
SUN RIVER SEC 02	Teton	NATIONAL FOREST - ELK CREEK	MISSOURI RIVER	47.9	3
SUN RIVER SEC 02	Teton	GIBSON DAM - NATIONAL FOREST	MISSOURI RIVER	4.8	3
SUN RIVER SEC 02	Cascade	ELK CREEK - MUDDY CREEK	MISSOURI RIVER	74.3	3
SUN RIVER SLOPE CANAL	Teton	PISHKUN RESERVOIR - NEAR FAIRFIELD	MUDDY CREEK	64.0	3
TETON RIVER SEC 01	Cascade	HWY 221 - MOUTH	MARIAS RIVER	265.5	3
TETON RIVER SEC 02	Teton	S FK - CHOTEAU	MARIAS RIVER	48.3	3
TILLINGHAST CREEK	Cascade	NEAR UPPER END - MOUTH	BELT CREEK	13.5	3
TOWNSEND CREEK	Pondera	HEADWATERS - MOUTH	S FK TWO MEDICINE RIVER	3.2	3
WALDRON CREEK	Teton	1.5 MI ABOVE MOUTH - MOUTH	N FK TETON RIVER	2.4	3
WHITEROCK CREEK	Pondera	HEADWATERS - MOUTH	S FK TWO MEDICINE RIVER	3.2	3
WOODS CREEK	Pondera	HEADWATERS - MOUTH	S FK TWO MEDICINE RIVER	2.4	3

Montana Rivers Study
Rivers with Fisheries Value Class 1
Oil & Gas Region No. 3

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
MISSOURI RIVER SEC 01	McCone	MILK RIVER - BIG MUDDY CREEK	MISSISSIPPI RIVER	176.2	1
MISSOURI RIVER SEC 01	McCone	BIG MUDDY CREEK - STATE LINE	MISSISSIPPI RIVER	88.0	1
MISSOURI RIVER SEC 05	McCone	FT PECK DAM - MILK RIVER	MISSISSIPPI RIVER	13.7	1
YELLOWSTONE RIVER SEC 01	Dawson	POWDER RIVER - INTAKE DIVERSION	MISSOURI RIVER	126.2	1
YELLOWSTONE RIVER SEC 01	Dawson	INTAKE DIVERSION - STATE LINE	MISSOURI RIVER	88.0	1

Montana Rivers Study
Rivers with Fisheries Value Class 2
Oil & Gas Region No. 3

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
BEAVER CREEK	Wibaux	LAMESTEER CREEK - STATE LINE	LITTLE MISSOURI RIVER	85.6	2
BOXELDER CREEK	Fallon	HWY 212 - STATE LINE	LITTLE MISSOURI RIVER	201.3	2
CABIN CREEK	Dawson	BRIDGE AT ULRICH FARM - MOUTH	YELLOWSTONE RIVER	14.5	2
COTTONWOOD CREEK	Wibaux	CASTLE/COTTONWOOD BELOW JCT - MOUTH	YELLOWSTONE RIVER	11.2	2
DEER CREEK	Dawson	NEAR OLD ABANDONED FARM HOUSE - MOUTH	YELLOWSTONE RIVER	29.0	2
E FK POPLAR RIVER	Daniels	STATE LINE - MOUTH	POPLAR RIVER	29.0	2
FOX CREEK	Richland	FORKS - MOUTH	YELLOWSTONE RIVER	6.9	2
O'FALLON CREEK	Fallon	MILDRED BRIDGE - MOUTH	YELLOWSTONE RIVER	33.6	2
O'FALLON CREEK	Fallon	SCHUMAKER SITE - MILDRED BRIDGE	YELLOWSTONE RIVER	30.4	2
O'FALLON CREEK	Fallon	BRIDGE ON BAKER RD - SCHUMAKER SITE	YELLOWSTONE RIVER	16.0	2
POPLAR RIVER SEC 01	Daniels	E FK - INDIAN RESERVATION	MISSOURI RIVER	30.0	2
POPLAR RIVER SEC 02	Daniels	STATE LINE - E FK	MISSOURI RIVER	48.0	2
REDWATER RIVER	McCone	WOLF CREEK - MOUTH	MISSOURI RIVER	51.0	2
REDWATER RIVER	Dawson	LISK CREEK - WOLF CREEK	MISSOURI RIVER	77.2	2
THIRTEENMILE CREEK	Dawson	MULLET SITE - MOUTH	YELLOWSTONE RIVER	19.3	2
UPPER SEVENMILE CREEK	Dawson	RED BARN SITE - MOUTH	YELLOWSTONE RIVER	22.5	2
W FK POPLAR RIVER	Daniels	STATE LINE - FT PECK INDIAN RESERVATION	POPLAR RIVER	95.6	2

Montana Rivers Study
Rivers with Fisheries Value Class 3
Oil & Gas Region No. 3

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
BENNIE PEER CREEK	Richland	125 M ABOVE MOUTH - MOUTH	YELLOWSTONE RIVER	0.8	3
BIG MUDDY CREEK	Roosevelt	4 MI W OF FROID - MOUTH	MISSOURI RIVER	43.4	3
BOX ELDER CREEK	Dawson	COUNTY RD - MOUTH	YELLOWSTONE RIVER	32.2	3
BURNS CREEK	Dawson	NEAR JCT SEC 32/33 - MOUTH	YELLOWSTONE RIVER	24.0	3
CEDAR CREEK	Dawson	NEAR LABELL EXCLOSURE - MOUTH	YELLOWSTONE RIVER	24.0	3
CLEAR CREEK	Dawson	TOM HOILLAND RANCH AT XING - MOUTH	YELLOWSTONE RIVER	17.6	3
CRANE CREEK	Richland	BELOW RR TRACKS AT CRANE - MOUTH	YELLOWSTONE RIVER	1.6	3
DUNLAP CREEK	Richland	BN RR TRACKS - MOUTH	YELLOWSTONE RIVER	1.0	3
FIRST HAY CREEK	Richland	FORKS - MOUTH	YELLOWSTONE RIVER	20.1	3
KRUG CREEK	Dawson	KRUG CREEK SCHOOL RD - MOUTH	GLENDIVE CREEK	17.7	3
LITTLE BEAVER CREEK	Wibaux	STATE LINE - MOUTH	BEAVER CREEK	8.0	3
LONE TREE CREEK	Richland	JCT SEC 19/30 - MOUTH	YELLOWSTONE RIVER	20.9	3
LOWER SEVENMILE CREEK	Dawson	ABOUT 5 KM N OF HWY AT HOUSE - MOUTH	YELLOWSTONE RIVER	3.6	3
MORGAN CREEK	Dawson	JCT SEC 35/36 - MOUTH	YELLOWSTONE RIVER	3.2	3
O'FALLON CREEK	Fallon	BRIDGE - BRIDGE ON BAKER RD	YELLOWSTONE RIVER	43.2	3
SANDSTONE CREEK	Fallon	HIWAY 12 SITE - MOUTH	OFALLON CREEK	25.7	3
SHADWELL CREEK	Richland	WICKS SITE - MOUTH	YELLOWSTONE RIVER	9.6	3
SMITH CREEK	Richland	C S CREEK - MOUTH	YELLOWSTONE RIVER	32.2	3
WAR DANCE CREEK	Dawson	200 M ABOVE MOUTH - MOUTH	YELLOWSTONE RIVER	0.1	3

Montana Rivers Study
Rivers with Fisheries Value Class 1
Oil & Gas Region No. 4

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
BIG SPRING CREEK SEC 01	Fergus	COTTONWOOD CREEK - MOUTH	JUDITH RIVER	13.2	1
BIG SPRING CREEK SEC 02	Fergus	UPPER FISH HATCHERY - HYW 19 BRIDGE	JUDITH RIVER	20.8	1
BIG SPRING CREEK SEC 02	Fergus	HWY 19 BRIDGE - COTTONWOOD CREEK	JUDITH RIVER	17.4	1
COLLAR GULCH	Fergus	HEADWATERS - SECTION 32/33 BOUNDARY	FORDS CREEK	3.2	1
MISSOURI RIVER SEC 06A	Fergus	BLAINE/CHOTEAU COUNTY BY - FT PECK RESERVOIR	MISSISSIPPI RIVER	125.7	1
N FK DEEP CREEK	Meagher	HEADWATERS - MOUTH	SMITH RIVER	7.2	1

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
BIGHORN RIVER SEC 01	Treasure	LITTLE BIGHORN RIVER - MOUTH	YELLOWSTONE RIVER	68.5	2
HALF MOON CREEK	Fergus	HEADWATERS - NATIONAL FOREST	N FK FLATWILLOW CREEK	6.4	2
IRON MINES CREEK	Meagher	FORKS - MOUTH	TENDERFOOT CREEK	3.2	2
LOST CREEK	Judith Basin	FALLS - FALLS/NAT FOREST BOUNDARY	BIG OTTER CREEK	1.0	2
MUSSELSHELL RIVER SEC 01	Musselshell	RTE 3 BRIDGE NEAR LAVINA - FLATWILLOW CREEK	FT PECK RESERVOIR	238.2	2
MUSSELSHELL RIVER SEC 01	Garfield	FLATWILLOW CREEK - MOUTH	FT PECK RESERVOIR	84.5	2
ROSEBUD CREEK	Rosebud	INDIAN RESERVATION - MOUTH	YELLOWSTONE RIVER	153.0	2
SARPY CREEK	Treasure	RESERVATION - MOUTH	YELLOWSTONE RIVER	84.2	2
SHEEP CREEK	Meagher	JUMPING CREEK - MOUTH	SMITH RIVER	43.6	2
SMITH RIVER SEC 02	Meagher	SHEEP CREEK - ROCK CREEK	MISSOURI RIVER	15.0	2
SMITH RIVER SEC 02	Meagher	FORT LOGAN BRIDGE - SHEEP CREEK	MISSOURI RIVER	24.5	2
TONGUE RIVER SEC 02	Rosebud	INDIAN RESERVATION - BEAVER CREEK	YELLOWSTONE RIVER	17.6	2
TONGUE RIVER SEC 02	Rosebud	INDIAN RESERVATION - INDIAN RESERVATION	YELLOWSTONE RIVER	56.8	2
TONGUE RIVER SEC 02	Rosebud	TONGUE RIVER DAM - INDIAN RESERVATION	YELLOWSTONE RIVER	89.4	2
YELLOWSTONE RIVER SEC 02	Rosebud	BIGHORN RIVER - CARTERSVILLE DIVERSION	MISSOURI RIVER	93.7	2

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
BIG DRY CREEK	Garfield	1 MI ABOVE MOUTH - MOUTH	FT PECK RESERVOIR	1.6	3
BIG HILL CREEK	Judith Basin	HEADWATERS - MOUTH	S FK JUDITH RIVER	2.4	3
CAMAS CREEK	Meagher	NATIONAL FOREST - MOUTH	SMITH RIVER	23.3	3
CAMAS CREEK	Meagher	HEADWATERS - NATIONAL FOREST	SMITH RIVER	8.8	3
COTTONWOOD CREEK	Meagher	SOURCE - FOREST LAKE	S FK MUSSELSHELL RIVER	3.2	3
DRY FORK BELT CREEK	Judith Basin	NEAR UPPER END - GALENA CREEK	BELT CREEK	5.6	3
E FK BIG SPRING CREEK	Fergus	5 MI ABOVE HEATH - MOUTH	BIG SPRING CREEK	20.0	3
FISHER CREEK	Meagher	HEADWATERS - MOUTH	TENDERFOOT CREEK	2.1	3
GOAT CREEK	Meagher	HEADWATERS - MOUTH	SMITH CREEK	2.9	3
HANGING WOMAN CREEK	Rosebud	FORK IN RD - MOUTH	TONGUE RIVER	9.6	3
HIGHWOOD CREEK	Judith Basin	CHOUTEAU COUNTY LINE - NATIONAL FOREST	MISSOURI RIVER	9.2	3
JEFFERSON CREEK	Judith Basin	FORKS - MOUTH	BELT CREEK	5.5	3
JUDITH RIVER SEC 01	Fergus	WARMSPRING CREEK - MISSOURI RIVER	MISSOURI RIVER	64.4	3
JUDITH RIVER SEC 02	Judith Basin	FORKS - ANTELOPE CREEK	MISSOURI RIVER	35.2	3
JUDITH RIVER SEC 02	Fergus	ROSS FORK CREEK - WARMSPRING CREEK	MISSOURI RIVER	48.3	3
LAKE CREEK	Meagher	HEADWATERS - CRATER LAKE (NAT FOREST)	N FK SMITH RIVER	2.4	3
LITTLE SULPHUR CREEK	Meagher	14 KM ABOVE MOUTH - 10 KM ABOVE MOUTH/CENTER SEC33	SMITH RIVER SEC 02	4.0	3
LOST FORK M FK JUDITH RIVER	Judith Basin	BURRIS CREEK - MOUTH	M FK JUDITH RIVER	10.2	3
LOUSE CREEK	Fergus	HEADWATERS - MOUTH	JUDITH RIVER	27.2	3
M FK JUDITH RIVER	Judith Basin	FORKS - MOUTH	JUDITH RIVER	20.6	3
MUSSELSHELL RIVER SEC 02	Golden	N & S FK MUSSELSHELL RIVER - DEADM BASIN SUPPLY CA	FT PECK RESERVOIR	89.0	3
MUSSELSHELL RIVER SEC 02	Golden	DEADM BASIN SUPPLY CANAL INLET - RTE 3 BRIDGE NEAR	FT PECK RESERVOIR	93.3	3
N FK MUSSELSHELL RIVER	Meagher	BAIR RESERVOIR - MOUTH	MUSSELSHELL RIVER	20.9	3
N FK MUSSELSHELL RIVER	Meagher	HEADWATERS - BAIR RESERVOIR	MUSSELSHELL RIVER	6.0	3
N FK SMITH RIVER	Meagher	HWY 89 - MOUTH	SMITH RIVER	14.5	3
N FK SMITH RIVER	Meagher	HEADWATERS - N FK DAM	SMITH RIVER	19.3	3
NEBEL COULEE	Judith Basin	HEADWATERS - SECTION 30/31 BOUNDARY	BIG OTTER CREEK	1.0	3
OTTER CREEK	Rosebud	POOL BELOW XING AT TRESSLERS - MOUTH	TONGUE RIVER	9.6	3
ROCK CREEK	Meagher	NEAR HEADWATERS - MOUTH	SMITH RIVER	31.4	3
ROSEBUD CREEK	Rosebud	N & S FK ROSEBUD CREEK - INDIAN RESERVATION	YELLOWSTONE RIVER	76.5	3
RUGBY CREEK	Meagher	HEADWATERS - MOUTH	TENDERFOOT CREEK	4.0	3
RUNNING WOLF CREEK	Judith Basin	NATIONAL FOREST - HWY 87 BRIDGE	WOLF CREEK	18.9	3
RUSSIAN CREEK	Judith Basin	NEAR HEADWATERS - MOUTH	S FK JUDITH RIVER	4.8	3
S FK DEEP CREEK	Meagher	HEADWATERS - MOUTH	SMITH RIVER	6.8	3
S FK JUDITH RIVER	Judith Basin	TRASH RANCH - MOUTH	JUDITH RIVER	10.8	3
S FK JUDITH RIVER	Judith Basin	NEAR HEADWATERS - TRASK RANCH	JUDITH RIVER	13.3	3
S FK MUSSELSHELL RIVER	Meagher	COTTONWOOD CREEK - MOUTH	MUSSELSHELL RIVER	11.5	3
S FK SMITH RIVER	Meagher	HUSSEY CREEK - MOUTH	SMITH RIVER	24.0	3
SHEEP CREEK	Meagher	JCT SEC 3/10 - JUMPING CREEK	SMITH RIVER	12.9	3
SIXTEENMILE CREEK	Meagher	HEADWATERS - HIGGINS RESERVOIR	MISSOURI RIVER	31.9	3
SIXTEENMILE CREEK	Meagher	HIGGINS RESERVOIR - SIXTEEN	MISSOURI RIVER	21.8	3
SMITH RIVER SEC 02	Meagher	ROCK CREEK - CANYON	MISSOURI RIVER	73.9	3

Montana Rivers Study
Rivers with Fisheries Value Class 3
Oil & Gas Region No. 4

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
SMITH RIVER SEC 02	Meagher	FORKS - FT LOGAN BRIDGE	MISSOURI RIVER	41.0	3
TENDERFOOT CREEK	Meagher	NATIONAL FOREST - MOUTH	SMITH RIVER	13.8	3
TENDERFOOT CREEK	Meagher	HEADWATERS - NATIONAL FOREST	SMITH RIVER	27.7	3
TONGUE RIVER SEC 01	Rosebud	BEAVER CREEK - T&Y DAM	YELLOWSTONE RIVER	119.0	3
WARM SPRINGS CREEK	Fergus	WARM SPRING - MOUTH	JUDITH RIVER	28.2	3
WEST ROSEBUD CREEK	Garfield	NATIONAL FOREST - MOUTH	ROSEBUD CREEK	29.3	3
WOLSEY CREEK	Meagher	JCT SEC 12/13 - MOUTH	SHEEP CREEK	7.2	3

Montana Rivers Study
Rivers with Fisheries Value Class 1
Oil & Gas Region No. 5

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
CROOKED CREEK	Carbon	HEADWATERS - STATE LINE	BIGHORN RIVER	15.4	1
YELLOWSTONE RIVER SEC 07A	Sweetgrass	REGION 3/SPRINGDALE - BOULDER RIVER	MISSOURI RIVER	29.3	1

Montana Rivers Study
Rivers with Fisheries Value Class 2
Oil & Gas Region No. 5

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
BIGHORN RIVER SEC 01	Yellowstone	LITTLE BIGHORN RIVER - MOUTH	YELLOWSTONE RIVER	68.5	2
BOULDER RIVER SEC 01	Sweetgrass	NATURAL BRIDGE - MOUTH	YELLOWSTONE RIVER	49.2	2
BOULDER RIVER SEC 02	Stillwater	ASPEN CAMPGROUND - NATURAL BRIDGE	YELLOWSTONE RIVER	14.4	2
LOWER DEER CREEK	Sweetgrass	HEADWATERS - NATIONAL FOREST	YELLOWSTONE RIVER	24.8	2
ROCK CREEK SEC 01	Carbon	RED LODGE - ROBERTS	CLARKS FORK RIVER	21.1	2
STILLWATER RIVER SEC 01	Stillwater	NYE - ROSEBUD CREEK	YELLOWSTONE RIVER	33.8	2
STILLWATER RIVER SEC 01	Stillwater	ROSEBUD CREEK - MOUTH	YELLOWSTONE RIVER	16.1	2
STILLWATER RIVER SEC 02	Stillwater	8.8 KM ABOVE NATIONAL FOREST - NATIONAL FOREST	YELLOWSTONE RIVER	8.8	2
STILLWATER RIVER SEC 02	Stillwater	SIOUX CHARLEY LAKE - 8.8 KM ABOVE NATIONAL FOREST	YELLOWSTONE RIVER	3.2	2
STILLWATER RIVER SEC 02	Stillwater	NATIONAL FOREST - NYE	YELLOWSTONE RIVER	6.4	2
YELLOWSTONE RIVER SEC 05	Yellowstone	PARK CITY - CLARKS FORK RIVER	MISSOURI RIVER	19.6	2
YELLOWSTONE RIVER SEC 05	Stillwater	STILLWATER RIVER - PARK CITY	MISSOURI RIVER	34.9	2
YELLOWSTONE RIVER SEC 06	Stillwater	BOULDER RIVER - STILLWATER RIVER	MISSOURI RIVER	69.0	2

Montana Rivers Study
Rivers with Fisheries Value Class 3
Oil & Gas Region No. 5

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
BAD CANYON CREEK	Stillwater	HEADWATERS - NATIONAL FOREST	STILLWATER RIVER SEC 02	6.4	3
BLUEWATER CREEK	Carbon	HEADWATERS - MCDOWELL COULEE	CLARKS FORK YELLOWSTONE RIVER	6.4	3
CASTLE CREEK	Stillwater	NATIONAL FOREST - MOUTH	W FK STILLWATER RIVER	8.0	3
CLARKS FK YELLOWSTONE SEC 2	Carbon	STATE LINE - BRIDGER	YELLOWSTONE RIVER	46.2	3
CLARKS FORK YELLOWSTONE SEC 01	Carbon	BRIDGER - MOUTH	YELLOWSTONE RIVER	65.3	3
EAST BOULDER RIVER	Sweetgrass	RD XING - NATIONAL FOREST	BOULDER RIVER	10.0	3
EAST BOULDER RIVER	Sweetgrass	LOW END PLACER BASIN - RD XING	BOULDER RIVER	7.6	3
EAST BOULDER RIVER	Sweetgrass	NATIONAL FOREST - MOUTH	BOULDER RIVER	9.3	3
EAST ROSEBUD CREEK	Carbon	FOSSIL LAKE - 0.5 KM ABOVE LAKE	ROSEBUD CREEK	17.7	3
EAST ROSEBUD CREEK	Carbon	EAST ROSEBUD LAKE - MOUTH	ROSEBUD CREEK	38.6	3
ELK CREEK	Sweetgrass	HEADWATERS - MOUTH	EAST BOULDER RIVER	7.2	3
FISHTAIL CREEK	Stillwater	NATIONAL FOREST - MOUTH	WEST ROSEBUD CREEK	19.6	3
HELLROARING CREEK	Carbon	HEADWATERS SYLVAN LAKE - MOUTH	EAST ROSEBUD CREEK	8.0	3
LAKE FORK ROCK CREEK	Carbon	HEADWATERS - MOUTH	ROCK CREEK	8.5	3
LINE CREEK	Stillwater	HEADWATERS - MOUTH	WEST ROSEBUD CREEK	5.8	3
LODGEPOLE CREEK	Stillwater	LIMESTONE SPRING - MOUTH	CASTLE CREEK	2.9	3
MORRIS CREEK	Carbon	6600 LEVEL TOPO MAP - NATIONAL FOREST	EAST ROSEBUD CREEK	2.3	3
MORRIS CREEK	Carbon	NATIONAL FOREST - MOUTH	EAST ROSEBUD CREEK	9.7	3
PICKET PIN CREEK	Sweetgrass	HEADWATERS - NATIONAL FOREST	CASTLE CREEK	11.2	3
ROCK CREEK SEC 01	Carbon	ROBERTS - BOYD	CLARKS FORK RIVER	13.7	3
ROCK CREEK SEC 01	Carbon	W FK ROCK CREEK - RED LODGE	CLARKS FORK RIVER	4.8	3
ROCK CREEK SEC 02	Carbon	STATE LINE - W FK ROCK CREEK	CLARKS FORK YELLOWSTONE RIVER	27.4	3
ROSEBUD CREEK	Stillwater	E & W ROSEBUD CREEKS - MOUTH	STILLWATER RIVER	6.0	3
SILVER CREEK	Stillwater	HEADWATERS - MOUTH	STILLWATER RIVER	1.6	3
TEPEE CREEK	Stillwater	HEADWATERS - MOUTH	BAD CANYON CREEK	2.4	3
TROUT CREEK	Sweetgrass	HEADWATERS - NATIONAL FOREST	STILLWATER RIVER	8.8	3
UPPER DEER CREEK	Sweetgrass	ASP GULCH - NATIONAL FOREST	YELLOWSTONE RIVER	5.8	3
W FK STILLWATER R SEC 01	Stillwater	CASTLE CREEK - MOUTH	STILLWATER RIVER	4.5	3
W FK STILLWATER R SEC 01	Stillwater	NATIONAL FOREST - CASTLE CREEK	STILLWATER RIVER	7.4	3
W FK STILLWATER R SEC 02	Sweetgrass	SEC 25A - NATIONAL FOREST	STILLWATER RIVER	12.7	3
WEST BOULDER RIVER	Sweetgrass	NATIONAL FOREST - MOUTH	BOULDER RIVER	22.9	3
WEST ROSEBUD CREEK	Carbon	ISLAND LAKE OUTLET - NATIONAL FOREST	ROSEBUD CREEK	17.3	3
WEST ROSEBUD CREEK	Stillwater	NATIONAL FOREST - MOUTH	ROSEBUD CREEK	29.3	3
WEST ROSEBUD CREEK	Stillwater	HEADWATERS - ISLAND LAKE OUTLET	ROSEBUD CREEK	12.7	3
YELLOWSTONE RIVER SEC 03	Yellowstone	HUNTLEY DIVERSION - BIGHORN RIVER	MISSOURI RIVER	90.4	3
YELLOWSTONE RIVER SEC 04	Yellowstone	CLARKS FORK RIVER - BILLINGS SOUTH BRIDGE	MISSOURI RIVER	19.8	3
YELLOWSTONE RIVER SEC 04	Yellowstone	BILLINGS SOUTH BRIDGE - HUNTLEY DIVERSION	MISSOURI RIVER	24.3	3

Montana Rivers Study
Rivers with Fisheries Value Class 1
Oil & Gas Region No. 6

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
YELLOWSTONE RIVER SEC 02	Powder River	CARTERSVILLE DIVERSION - POWDER RIVER	MISSOURI RIVER	141.5	1

Montana Rivers Study
Rivers with Fisheries Value Class 2
Oil & Gas Region No. 6

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
BOXELDER CREEK	Carter	HWY 212 - STATE LINE	LITTLE MISSOURI RIVER	201.3	2
LITTLE MISSOURI RIVER	Carter	STATE LINE - STATE LINE	MISSOURI RIVER	110.1	2
O'FALLON CREEK	Carter	MILDRED BRIDGE - MOUTH	YELLOWSTONE RIVER	33.6	2
O'FALLON CREEK	Carter	SCHUMAKER SITE - MILDRED BRIDGE	YELLOWSTONE RIVER	30.4	2
O'FALLON CREEK	Carter	BRIDGE ON BAKER RD - SCHUMAKER SITE	YELLOWSTONE RIVER	16.0	2
POWDER RIVER	Custer	STATE LINE - MOUTH	YELLOWSTONE RIVER	350.0	2
TONGUE RIVER SEC 01	Custer	T & Y DAM - MOUTH	YELLOWSTONE RIVER	21.0	2

Water Name	County	Boundaries	Tributary to	Length (km)	Value Class
COAL CREEK	Custer	REMAINS OF OLD BRIDGE - MOUTH	POWDER RIVER	6.4	3
CUSTER CREEK	Custer	S OF RES TAKE TRAIL - MOUTH	YELLOWSTONE RIVER	11.2	3
HARRIS CREEK	Custer	LEO HAUGHIANS RANCH - MOUTH	YELLOWSTONE RIVER	0.5	3
LITTLE POWDER RIVER	Powder River	STATE LINE - MOUTH	POWDER RIVER	106.9	3
LOCATE CREEK	Custer	NEXT TO TURN-OFF TO JIM GRAHAM - MOUTH	POWDER RIVER	12.8	3
MIZPAH CREEK	Custer	SAND CREEK - MOUTH	POWDER RIVER	83.2	3
OTTER CREEK	Powder River	POOL BELOW XING AT TRESSLERS - MOUTH	TONGUE RIVER	9.6	3
OTTER CREEK	Powder River	XING AT BADGETT RANCH BLDGS - BRIDGE AT TRESSLER'S	TONGUE RIVER	17.6	3
PENNEL CREEK	Custer	RR CULVERT SITE - MOUTH	OFALLON CREEK	7.2	3
PUMPKIN CREEK	Custer	TONGUE RIVER RD BRIDGE - MOUTH	TONGUE RIVER	0.7	3
PUMPKIN CREEK	Custer	FIRST CREEK - TONGUE RIVER RD BRIDGE	TONGUE RIVER	26.6	3
SUNDAY CREEK	Custer	N&S SUNDAY CREEK - MOUTH	YELLOWSTONE RIVER	23.3	3
TONGUE RIVER SEC 01	Custer	BEAVER CREEK - T&Y DAM	YELLOWSTONE RIVER	119.0	3

TECHNICAL APPENDIX 7
NOISE

Sound levels in rural Montana settings are generally low, with most sounds from natural sources (wind, water, animals). In areas of dispersed human activity, such as forests and agricultural areas, sound levels depend on the sound location and any local screening or sound muffling conditions. Sound sources in cities and towns include traffic noise and business and industrial operations. Petroleum drilling and field development operations produce characteristically industrial sounds from trucks, diesel motors, drilling machinery, pumping operations, and pipeline compressor stations.

Most sound-measuring methods record sound levels or decibels (dBA) over a period of time and logarithmically average them to derive an average sound level (Engineering Dynamics 1984). Since decibels are logarithmic units (i.e. an increase of 10 decibels is a 100 percent increase in perceived loudness), sound levels cannot be added by ordinary arithmetic means (BLM 1982). The Environmental Protection Agency has extended this method to describe the average sound of a 24-hour period. This method, the Loudness-Day-Night (Ldn) incorporates a 10 dBA quietness correction for sound levels between 10 p.m. and the following 7 a.m. This nighttime 10 dBA adjustment is to account for quieter nighttime background noise levels and community expectations regarding sleep interference (Stolen 1980). In practical terms, this means that nighttime noise should be no more than half as loud as daytime noise (a decrease of 10 dBA) (Engineering Dynamics 1984).

Because of the wide variety and constant changes in potential acoustical environments, it is difficult to precisely describe the noise levels surrounding a particular source. However, the decibel scale using the A-weighted scale (dBA) is the most widely used measurement of human perceived sound intensity (Stolen 1980). The dBA scale is logrithmic, such that a 10 decibel increase represents a doubling in the perceived loudness (100 percent increase in perceived loudness). Thus, the 40 dBA sound level typical of a quiet office seems twice as loud as the 30 dBA of a quiet home late at night but sounds half as noisy as the 50 dBA level of a normal conversation. Some reference sound levels are 60 dBA in a busy downtown area, 80 dBA from a garbage disposal, 100 dBA 25 feet from an unmuffled motorcycle, and approximately 120 dBA at the tailpipes of an unmuffled motorcycle (BLM 1985b; Kruger 1987).

Logging, ranching, farming, mining, or vehicle travel cause elevated sound levels in the immediate vicinity of the activity, but these locations are generally widely dispersed and away from human residences.

Sound sources in urban residential areas include pets, children, television, radio, telephones, and occasional traffic, which can increase ambient noise levels up to about 40-55 dBA (McGuiness et al. 1980). These background noises generally are comfortable for most residents. Occasional loud noises such as truck traffic, lawnmowers, or chain saws create noise levels substantially above these typical background levels.

City- and town-developed areas have moderate noise levels (usually from 55 to 65 dBA) caused by traffic, business, and industrial operations (BLM 1982; Dames and Moore 1986).

Major travel corridors have elevated noise levels from motor vehicle travel, up to 95 dBA for a large noisy truck, and from jet aircraft, up to 110 dBA for a low-level jet aircraft flyover (Dames and Moore 1986). Large industrial operations and unmuffled equipment (such as a chainsaw or jackhammer) may produce over 130 dBA (Dames and Moore 1986).

DRILL SITE ACCESS AND SITE PREPARATION

Smaller Drilling Sites

In the Northern Montana district, single derrick truck rigs are often driven directly to the drill site across level country, and if the site is sufficiently level, it becomes the drill pad without significant construction activity. A small reserve pit is dug nearby. Noise levels of up to 90 dBA are typically produced for up to two days by the drill truck engine, drill pad preparation (when necessary), and excavation of the reserve pit (Dames and Moore 1986).

Larger Drilling Sites

The jackknife double-derrick rigs commonly used in northern and central Montana, and the triple-derrick rigs that predominate in the Big Horn Basin, Overthrust, Powder River and Williston Basin districts require construction of 12-to-16-foot-wide bladed vehicle roads. Still higher quality roads with gravelled surfaces are sometimes needed in the Overthrust Belt.

Construction of the 2-to-5 acre level drill pad required for the double and triple rigs is done with earthmoving equipment. At larger or more remote sites, access road construction and drill pad construction can involve a three-man crew for up to two weeks. The earthmoving equipment may include up to two push/pull scrapers, two D-8 caterpillar tractors, and a motor patrol grader. This equipment generates daytime noise levels of up to 115 dBA (DSL 1984).

DRILLING OPERATIONS

Single Derrick Drilling Rig

The truck mounted drilling rigs used to drill relatively shallow gas wells in northern Montana are served on-site by water trucks, a mud truck, a well tester, and other well service vehicles. The actual well drilling is continuous, taking an average of 48 hours. The well service trucks generate up to 95 dBA when driving to and from the well site. A small drill rig engine may produce up to 110 decibels (BLM 1980a). The drilling rig also may produce loud squeals and booms when braking and adding pipe. These variable noise levels are generally considered to be more noticeable and objectionable than equivalent levels of relatively constant noise (McGuinness et al. 1980; Dames and Moore 1986).

Double and Triple Derrick Drilling Rigs

Double and triple derrick rigs commonly are powered by two 400 horsepower diesel engines in the case of double derrick rigs, or three 300 to 600 horsepower diesel engines for triple derrick rigs. The deeper the well, the more powerful the rig. Often additional diesel engines are used to power the rig's electrical system and mud pumps. The main diesel engines may directly power the drill head (in diesel-powered rigs) or the engines may drive a set of electrical generators which power large electric motors that drive the drill head (in diesel electric rigs). The diesel electric rig produces a relatively constant noise level, but diesel-powered rig noise fluctuates with changes in drilling operations (Dames and Moore 1986).

Up to 50 large trucks are used to haul the rig to the drill site. Each of these trucks may produce up to 95 dBA of noise (Dames and Moore 1986). Depending on the well, assembling the drilling rig can take up to one week and generally occurs during daylight hours. Although there are significant noises from the diesel motors and rig assembly operations, these sounds are intermittent in nature and their impacts are difficult to predict.

The noise impacts generated during drilling operations result primarily from the diesel motors used to power the drill, the drilling operations itself (including tripping, braking and drill pipe movement), and from associated support activities, such as water, mud, and cement operations. The diesel engines on the drill rig can produce from 100 to 110 dBA of noise at the exhaust pipes and may operate 24 hours a day (BLM 1980a; DSL 1984). Depending upon the well depth and drilling conditions, drilling may take an average of one week in northern and central Montana (3,500 to 5,000 foot wells), three weeks in the Big Horn and Powder River Basins (7,500 foot wells), two months in the Williston Basin, and three to six months in the Overthrust Belt. Additional intermittent drilling noises are generated by tripping, draw works braking, and pipe handling operations. These noises, particularly the draw works brake squeal, although occasional, are very noticeable and intrusive (DSL 1984). Well servicing and road maintenance operations can generate up to 95 dBA at the truck exhaust pipes (Dames and Moore 1986). These activities may not only create noise in the areas surrounding the access routes and well site but may exceed the 90 dBA eight-hour worker exposure limits recommended by the Occupational Safety and Health Administration.

WELL SITE RECLAMATION

The reclamation of abandoned drill sites produces noise similar to that of drill site construction (up to two weeks of dirt moving producing up to 115 dBA during daytime operations).

WELL COMPLETION AND RELATED ACTIVITIES

Producing wells generate noise up to 105 dBA during a variety of activities, including well fracturing, production testing, and installation of well casings (DSL 1984). These activities are intermittent and take place for periods as long as three weeks.

As part of the well completion operations, the well pad is reshaped to accommodate oil transportation either by truck or pipeline. This normally

involves earthmoving operations that reduce the pad to less than 2 acres. The earthmoving equipment creates noise up to 115 dBA (Dames and Moore 1986).

EXTRACTION AND TRANSPORTATION

The shallow gas wells in northern and central Montana require few surface facilities. A well meter is often the only on-site facility. Some sites have a dehydration unit, a small refrigeration unit, or a line heater. All of this equipment is small and creates little noise.

Rather than have small dehydration and liquid recovery units scattered about the gas field, it is more typical to tie the wells together with a gathering system and pipe the gas to a centralized gas processing facility. Individual wells sometimes have insufficient wellhead pressure to reach the processing plant, so compressor plants are used to boost the pipeline pressure. The compressor plants produce approximately 105 dBA and operate 24 hours a day (Kruger 1987).

Producing oil wells may require horsehead pumps, field injection pumps, heater-treaters, water disposal pumps, pumping stations, and oil field trucks, all of which generate noise.

Horsehead pumping units come in a variety of sizes and with different power sources. The electric-powered pumping units are relatively quiet, producing about 65 dBA (Kruger 1987), while single cylinder ("Ajax" type) and multiple cylinder pumping engines create 95-100 dBA at unmuffled exhaust pipes (BLM 1980a). The multiple cylinder engines are generally quieter than the Ajax engines.

Heater treaters, water disposal pumps, and oil field pumping stations generally produce less than 65 dBA. The oil field service trucks and tank trucks may produce up to 95 dBA at the exhaust pipes (Dames and Moore 1986).

TECHNICAL APPENDIX 8
RECREATION AND AESTHETICS

VISUAL MANAGEMENT SYSTEMS

The Visual Management System of the U.S. Forest Service (1974) and the Visual Resource Management System of the U.S. Bureau of Land Management (1980b) are conceptually similar. Both systems initiate the visual management process by inventorying the scenic quality of the lands they manage. The variety of visual elements (form, line, color, and texture) is evaluated to determine landscapes of distinctive, common, or minimal visual quality. Sensitivity levels--a measure of people's concern for the visual resource--is evaluated next. In determining the vulnerability of areas to scenic degradation, both systems consider travel routes, areas of use, water bodies, and public concern for scenic values. Both systems incorporate distance of views from viewers--foreground/middleground, background, and "seldom seen"--into the analysis. Each system combines the above criteria to arrive at measurable objectives for managing the visual resource. The Forest Service and BLM both specify degrees of acceptable alteration to the landscape.

Visual quality objectives and management classes for Forest Service and BLM lands can be ranked according to the degree of visual alteration allowed for management activities. Most restrictive is the Forest Service visual quality objective of <u>preservation</u>, allowing ecological changes only. For the BLM, the parallel Management <u>Class 1</u> allows natural ecological changes and very limited management activities. These management objectives apply to wilderness areas, wild and scenic rivers, primitive areas, and other unique management units.

For areas having a visual quality objective of <u>retention</u> (FS) or that are in management <u>Class 2</u> (BLM), management activities ranging from ski areas and clearcuts to roads and visitor centers should not be visually evident. These objectives typically apply to major travel routes, roads and trails, use areas, or water bodies in areas of high scenic quality. These areas will also have a high degree of viewer sensitivity to visual change.

Next in rank are areas assigned a visual quality objective of <u>partial retention</u> (FS) or management <u>Class 3</u> (BLM) where management activities remain visually subordinate in the existing landscape. These designations cover a variety of landscapes ranging from high to low visual quality and highest to average viewer sensitivity. Management areas typically include secondary travel routes, use areas of local rather than regional importance, and those with lower use levels than areas having more restrictive management.

For areas having a management <u>Class 4</u> designation (BLM) or a visual quality objective of <u>modification</u> (FS), management activities may visually dominate the landscape. Typically applied to areas of moderate to low visual quality having lower viewer sensitivity, these designations allow greater flexibility in the siting and design of management activities than those mentioned previously.

The last category of <u>maximum modification</u> (FS) or <u>Class 5</u> (BLM) is applied to areas where management activities may be out of scale, incongruent,

Table 8-1. Montanans' 1985 Participation Rates for Outdoor Recreation Activities.

Travel/Nature-Based Activities	Percent of Adult Population Participating	Median Days Participating
Day hiking	77.1	30
Camping	51.9	8
Bicycling	38.6	20
Hunting	37.6	10
Nature study	31.8	21
Off-road 4WD	24.1	7
Jogging	23.8	25
Horseback riding	22.3	6
Backpacking	14.4	6
Motorcycling or ATV	11.5	10
Picnicking	7.4	6
Water-Based Activities		
Fishing	56.4	12
Lake or stream swimming	42.3	7
Pool swimming	35.3	7
Motorboating	32.6	5
Rafting	18.1	3
Water skiing	14.5	4
Canoeing	11.4	4
Winter Activities		
Alpine skiing	18.8	6
Cross-country skiing	18.6	7
Snowmobiling	16.3	5
Ice skating	12.9	3
Organized Games and Sports		
Lawn games	39.1	5
Target shooting	28.2	5
Baseball/softball	24.1	7
Golf	20.0	10
Basketball	15.2	10
Tennis	11.2	9
Football	6.7	4
Soccer	3.2	5

Source: J.E. Frost and S.F. McCool, The Montana Outdoor Recreation Needs Survey (Missoula, MT: University of Montana, School of Forestry). 1986.

and visually dominant within the viewed landscape. This classification is often applied to areas where changes have lowered visual quality to unacceptable levels and improvement is needed.

SUMMARY EXISTING RECREATION IN THE STATE

A 1985 survey of Montana residents (Frost and McCool 1986) identified participation rates for many outdoor recreation activities. These activities can be grouped into four categories--travel and nature-based activities, water-based activities, winter activities, and organized games and sports. Table 8-1 presents these participation rates. Over the next decade, participation in these activities is expected to increase, though at a rate less than the rate of population growth in Montana.

Existing Recreation on DFWP Lands

Table 8-2 tabulates elements of the state park system by oil and gas region. With 369 current sites statewide within the state park system, there are numerous opportunities for outdoor recreation at developed sites. Nearly two-thirds of these sites (62 percent) occur in oil and gas Region 1, with the remainder distributed among the other five regions. Regions 3 and 6 have the lowest numbers of developed sites, with regions 2, 4, and 5 forming a middle category across the central part of the state.

Table 8-2. Distribution of DFWP Recreation Sites Among Oil and Gas Regions.

Oil and Gas Region	State Recreation Areas	Fishing Access Sites	State Parks	State Monuments	Total
1	56	155	8	11	230
2	12	32	1	5	50
3	2	8	1	3	14
4	5	18	--	1	24
5	4	36	--	5	45
6	1	4	1	--	6
TOTAL	80	253	11	25	369

Source: Field Services Division, DFWP, Lands Section, Helena, MT. Computer printout. Spring 1988.

Data on numbers of recreational visits to state park system sites is presented in Table 8-3. Department of Fish, Wildlife and Parks administrative regions (which roughly correspond to oil and gas regions) also are shown. Sixty-four percent of total recreation visits occurred in oil and gas Region 1 during the summer of 1986, paralleling the 62 percent of developed sites which are also present there. Other recreation visits are again distributed among the remaining regions, with DFWP regions 4 and 5 roughly equal at 13 and 12 percent of total visits, and DFWP Region 6 the lowest at 2 percent. Figures show a pattern of increasing recreation visitation at DFWP sites statewide. A 45 percent increase in statewide cumulative visitation has occurred over the 6-year period from 1980 to 1986.

Table 8-3. Estimated Recreation Visits (in 1,000s) to State Park System Sites - 1986.

DFWP Administrative Region	Oil & Gas Region	Overnight Visits	Day Use Visits	Summer Total Visits	Percent of Total Visits
1	1	129	630	759	18
2	1	73	384	457	11
3	1	83	555	638	15
4	2,4	104	442	546	13
5	4,5	84	440	524	12
6	2,3	12	85	97	2
7	4,6	19	352	371	9
8	1	56	748	804	19
TOTAL		559	3636	4195	99

Source: Parks Division, DFWP, Helena, MT. Montana State Parks Visitation. 1986.

Existing Recreation on National Forests

Besides providing opportunities for recreation at developed sites, national forests also provide innumerable opportunities for dispersed recreation. Such activities as hunting, day hiking, fishing, backpacking, berry picking, firewood gathering, trail biking, and scenery viewing occur on national forests in a dispersed setting. Snowmobiling and skiing are popular winter activities.

Recreation use on national forests is highly seasonal. Summer recreation use tends to be concentrated on weekends, with peak use periods occurring on summer holidays. Hunting occurs in the fall, with the highest use in September and November. Winter use by skiers and snowmobilers will typically occur from December to March in locations open to winter travel.

National forests are inventoried for existing recreation opportunities and are classified into recreation settings based on their visual quality, the concentration and type of recreation user, and whether or not motor vehicle use is permitted.

These categories of recreation settings are:

1) semi-primitive non-motorized - a predominantly natural environment of moderate-to-large size with low interaction between users where motorized use is not permitted.

2) semi-private motorized - a predominantly natural environment of moderate-to-large size with low concentration of users and motorized use permitted.

3) roaded natural appearing - predominantly natural appearing environments with harmonizing evidence of the sights and sounds of man. Conventional motorized use is provided for in construction of roads.

4) roaded - areas predominantly characterized by the sights and sounds of man. Interaction between users may be moderate and conventional motorized use is provided for in construction of roads.

5) rural - areas with a substantially modified natural environment. Interaction between users is moderate to high and facilities for motorized use are available.

Recreation use on Montana's ten national forests can be grouped into developed and dispersed recreation. Table 8-4 shows 1986 recreational use data for national forests, grouped by oil and gas regions. Eight of the ten forests are located almost entirely within oil and gas Region 1. The remaining two forests--the Lewis and Clark and Custer National Forests--are split between oil and gas regions. The Rocky Mountain Division of the Lewis and Clark National Forest is grouped with those in Region 1 because of shared "Front Range" characteristics. The remaining division of the forest is located primarily in oil and gas Region 4. The Custer National Forest is split between regions 5 and 6 as shown in Table 8-4.

Table 8-4. Recreation Visitor Days on National Forests in Montana - 1986.

		Estimated Recreation Visitor Days (1,000's)	
Oil and Gas Region	National Forest	Developed Sites	Dispersed
1	Beaverhead	153.3	708.0
	Bitterroot	80.6	303.0
	Deerlodge	269.9	804.3
	Flathead	193.5	489.7
	Gallatin	487.6	1,364.2
	Helena	22.6	128.9
	Kootenai	336.1	825.1
	Lewis and Clark (Rocky Mountain Division)	61.7	242.3
	Lolo	265.6	1,140.5
2 & 3	---		
4	Lewis and Clark (Jefferson Division)	274.7	345.3
5	Custer (Beartooth Division)	177.6	336.9
6	Custer (Ashland Division)	5.1	30.7

Source: U.S. Forest Service, National Forest Recreation Inventory Management System. Computer printout. Spring 1988.

Dispersed recreation use on national forest lands ranges from two to three times that for developed site recreation use. Although recreation use

at developed sites was fairly stable from 1976 to 1986, dispersed recreation use grew steadily. Developed site use on national forests totaled 2.3 million recreation visitor days (RVD) in both 1976 and 1986, with use peaking at 2.9 million RVD in 1981. In contrast, dispersed use has seen a steady growth from 5.5 million RVD in 1976 to 6.8 million RVD in 1986. The peak use year was 1985 with 7.7 million recreation visitor days.

A listing of developed recreation sites on federally managed land in Montana is shown in Table 8-5. While most sites are campgrounds, others are only day-use areas with limited facilities. Designated areas and uses change from year to year. The land managing agency can provide the most up-to-date information on facilities and sites.

Table 8-5. Distribution of Federal Recreation Sites Among Oil and Gas Regions.

Oil and Gas Region	Forest Service Sites	BLM Sites	Other*	Total
1	143	5	16	164
2	6	5	14	25
3	---	--	2	2
4	10	3	--	13
5	23	--	3	26
6	5	1	--	6
TOTAL	187	14	35	236

* Includes national monuments, battlefields, recreation areas, historic sites, wildlife refuges, and reservoir sites.

Sources: DFWP, Field Services Division, Lands Section. 1988.
Department of Commerce, Montana Promotion Division. Montana Travel Planner. 1988.

The statewide distribution pattern of developed recreation sites that was evident for DFWP sites is again present for federally managed sites. The lowest number of sites (2 and 6) is found in oil and gas regions 3 and 6 in the eastern part of the state, with an increasing number of sites (13 to 26) in regions 2, 4, and 5 across the central portion of Montana. The greatest number of developed sites (187) is in oil and gas Region 1, the western third of the state.

Existing Recreation on BLM Lands

Recreation on BLM lands is primarily dispersed. While most lands are undeveloped or semi-developed for recreation, they do provide an important part of the statewide recreation spectrum. Popular recreation activities include hunting, fishing, floating, horseback riding, camping, and sightseeing. Popular winter activities are cross-country skiing, snowmobiling, and snowshoeing.

Developed campgrounds and day-use areas are primarily found along highways, rivers, and lakes. The distribution of these sites is shown in Table 8-6.

Recreation use data for developed sites and dispersed use is shown in Table 8-6. Use estimates are approximate and only trends in recreational use can be reliably obtained from the data. These trends show an increasing use in both developed recreation sites and dispersed uses on BLM land over the 5-year period from 1982 to 1987.

Table 8-6. Estimated Recreation Visits on BLM Lands in Montana.

Oil and Gas Region	District	Year	Developed Sites	Dispersed Use *
1	Butte	1982	250	900
		1983	270	1200
		1984	275	1300
		1985	260	1350
		1986	280	1500
2, 4, 5	Lewistown	1983	---	86.1
		1984	---	102.8
		1985	---	106.6
		1986	---	98.2
		1987	---	174.8
3, 6	Miles City	1982	33	103
		1983	33	104
		1984	33	112
		1985	33	112
		1986	34	113
		1987	35	113

* Use estimates may vary depending on how data is collected in any given year.

Recreation Types: 1. Developed Recreation - The type of recreation that occurs where modifications (improvements) enhance recreation opportunities and accommodate intensive recreation activities in a defined area.
2. Dispersed Recreation - That type of recreation use related to and in conjunction with roads and trails that requires few if any improvements and may occur over a wide area. Activities tend to be day-use oriented and include hunting, fishing, berrypicking, off-road vehicle use, hiking, horeseback riding, picnicking, camping, viewing scenery, snowmobiling, and many others.

Source: BLM district offices, Butte, Lewistown, and Miles City, MT. Computer printouts. Spring 1988.

Private Land Recreation

Table 8-7 presents locations for some of these recreation sites on private lands. Dude ranches and resorts are primarily found in the western part of the state, though guest ranches can be found in all areas. Data do not include ranches that are unlisted with the Montana Department of Commerce. Private campgrounds and recreational vehicle parks also are located predominantly in the western part of the state. Their distribution also follows the general pattern for all types of recreation development--lowest

concentrations in the eastern part of the state with increasing numbers of sites in western Montana.

Table 8-7. Location of Privately Owned Recreation Sites in Montana.

	Oil and Gas Region						
	1	2	3	4	5	6	Total
Ranches, resorts, and hot springs	74	9	0	8	12	2	105
Private campgrounds, KOA's, and RV parks	176	21	9	5	19	4	234
Total	250	30	9	13	31	6	339

Source: Montana Department of Commerce, Montana Promition Division, Helena, MT. Montana Travel Planner. 1988.

Most private campgrounds and recreational vehicle parks are located adjacent to or near federal and state highways in developed settings. In contrast, dude ranches and resorts are primarily located in more natural and scenic settings that offer access to mountains, rivers and streams, and wide open spaces. These less developed settings provide the backdrop for a wide range of outdoor activities.

Outfitters:

Table 8-8 shows the statewide distribution of purchased licenses by outfitters. Generally the location of outfitters' activities will correspond to these regions also, depending on permits that are obtained from land-managing agencies and agreements worked out with private landowners. The statewide distribution of licensed outfitters again follows the pattern for other recreation sites and use figures, with two-thirds (67 percent) of licensed outfitters in western Montana, 23 percent in central Montana, and 10 percent in the east.

Table 8-8. Licensed Outfitters in Montana by DFWP Administrative Regions - 1986-87.

DFWP Administrative Region	General Licenses	Day-hunting	Day-fishing	Both Dayhunting and Dayfishing	Total by Region
1	44	8	9	13	74
2	61	13	14	20	108
3	109	16	63	46	234
4	47	19	4	12	82
5	24	3	11	21	59
6	7	3	1	0	11
7	8	29	1	11	49
Total	300	91	103	123	617

Source: Montana Department of Commerce, Board of Outfitters. Helena, MT.

STATEWIDE PATTERNS IN RECREATION AND AESTHETIC IMPACTS

In most cases, oil and gas development in the eastern two-thirds of the state has been compatible with dispersed recreation activities. Where oil and gas development has adversely affected recreation, it typically has been a short-term intrusion from exploratory activities or a longer term change as an oil and gas field is developed. There are not many examples of oil and gas development adversely affecting designated recreation sites. The following descriptions characterize typical recreation impacts in the northern, central, and eastern parts of Montana.

Cumulative impacts of oil and gas development on recreation in Hi-Line oil and gas fields range from minor in the Kevin-Sunburst and Cut Bank fields to moderate in the Sweetgrass Hills (BLM 1988b). Long-term impacts from future development along the Hi-Line could include increased recreational access, contributing to increased erosion and hunting pressure, disturbance of primitive recreational values, and a shift from natural to more developed settings. Development in the Bowdoin Field in Phillips and Valley counties along Montana's Hi-Line has resulted in improved roads and better access for hunters and recreationists (Hauck 1988).

The Leroy Field in north-central Montana straddles the Upper Missouri Wild and Scenic River Corridor. This is a shallow natural gas field with 30 producing wells and 11 shut-ins on 320-acre spacing. While most land within the corridor is managed by the BLM and is currently exempt from federal leasing, other land is state or privately owned and may be leased or available for leasing. One producing well and one shut-in well are within the corridor, but no existing wells are visible from the river (Mitchell 1988). Further development in this area could change its remote and primitive character. Impacts could be at least partly avoided by careful siting of wells, access roads, gathering pipelines, and reclamation.

The Elk Basin Field is located primarily on public land south of Bridger in Carbon County. It receives heavy recreation use because of its proximity to Billings. As of 1986, this field had 52 producing oil wells and 27 shut-ins. Hunting is the primary dispersed use in this area, with disturbance of cultural artifacts a major concern for BLM area manages (McIlvain 1988).

The Rookery State Recreation area northwest of Havre is located within the Fresno gas field and currently has three producing gas wells. This day-use area is used mainly for hunting and some fishing on the Milk River. Impacts are minimal at this time (Martinka 1988). Prior to drilling, DFWP negotiated a mitigation package with the drilling operator, stipulating reclamation of the drill pads and gathering pipelines, approval of a planting mixture for revegetation, monitoring for successful revegetation, construction of a parking area for hunters, and a monetary payment.

Makoshika State Park near Glendive in Dawson County provides one example of potential problems resulting from possession of surface and minerals by different owners. Surface ownership in the park planning area is split among the DFWP, BLM, county, and private landowners. Mineral ownership is held by the BLM and private owners. Two exploratory wells were drilled on BLM land in the park planning area in the early 1980s, and access roads were built across private land to the well sites. Both wells subsequently were capped and well

pads reclaimed, but access roads were not reclaimed. Access by hunters and off-road vehicle recreationists is now difficult to control, creating problems for both private landowners and park managers. Coordination among surface and mineral owners within the park planning area could have incorporated site-specific stipulations into permits for maintenance of park resources (Conklin 1988; Monger 1988).

MITIGATION - RECREATION AND AESTHETICS

Mitigation on Federal Lands

Various strategies are available for avoiding or reducing impacts from drilling oil and gas wells. A federal mineral lease was issued on Custer National Forest for a site south of Red Lodge but stipulated that there could be "no surface occupancy." This led Amoco, the driller, to drill from adjacent private land, using directional drilling to reach the drilling target inside forest boundaries (Dames and Moore 1986). BLM issued the lease after reviewing and approving the proposed drilling. Several special stipulations were attached to the lease and permit to drill to address environmental concerns. Measures dealt with hydrogen sulfide safety, drilling only from Labor Day to May 1 to avoid peak recreation use times, and measures for supplemental feeding if elk were driven off winter range by drilling activities. Visual mitigation measures sought to minimize impact by reducing the size of the drill pad and storage of materials on-site and designing or treating permanent facilities to blend with the surrounding area.

Mitigation on State Lands

For state-owned lands, several options are available to minimize recreation and visual impacts. The mitigation package negotiated for the Rookery State Recreation Area is an example of available measures (see "Recreation Impacts").

Potential visual impacts from the proposed Cenex well on the Coal Creek State Forest west of Glacier National Park were assessed for viewpoints on the North Fork "scenic" River segment, the North Fork Road, from nearby residential areas, and from Glacier National Park. Several measures were proposed to mitigate off-site visual impacts. These included prompt recontouring and revegetation with native grasses and conifers following completion of any project phase and painting the drilling mast in forest tones if drilling were to occur between June and September. In case the well were to be a producer, permanent storage facilities would be needed, and these would be painted forest tones. A new access road system was to be designed if production were to occur.

Memoranda of understanding (MOU) offer another option for addressing recreation and visual concerns on state lands. Where state oil and gas leases are near or within identified sensitive recreation areas, MOUs can stipulate conditions for leasing or development to protect these resources. Examples of MOUs for recreation sites and areas include those for the Upper Missouri Wild and Scenic River Corridor and a proposed MOU for Makoshika State Park Area of Management Concern.

The MOU between the Department of State Lands and BLM for the Upper Missouri Wild and Scenic River corridor provides procedures for cooperative management and interagency cooperation. For oil and gas leasing on state lands within or affecting the river corridor, procedures call for DSL to notify BLM of proposed leases potentially affecting river management, and to provide an opportunity for BLM to comment. DSL also evaluates state lands within the corridor for their cultural, natural, and recreational resources, and notifies lease holders that the river corridor is being managed to protect these values.

The proposed MOU among DFWP, BLM, and Damson County for Makoshika State Park Area of Management Concern addresses the exploration, leasing, and use of mineral resources on those lands. The agreement calls for no leasing or extraction of minerals on DFWP and county lands, and leasing of oil and gas on BLM lands only with specified restrictions and stipulations. These include timing restrictions, restrictions on road use to maintain park safety, and restriction on distance from park developments.

Mitigation on Private Land

While fewer administrative controls may be available to address recreation and visual concerns on private land, the measures used to address these impacts on public land would be equally effective for use on private land where similar concerns exist. In the case of the Sohio-Moats exploratory oil and gas well in Bridger Canyon near Bozeman, the Bridger Canyon Planning and Zoning Commission attached several stipulations to its approval of the conditional use permit. Painting of the drill mast was not required for safety reasons, but review and approval of plans for screening or camouflaging of production facilities was required. Individual landowners may choose to incorporate measures to preserve visually sensitive settings in their lease agreements. Instances where recreation and visual concerns are issues become more complex in cases of split estate where the surface owner does not have the option of protecting surface values.

A decision by the Wyoming Supreme Court (Gulf Oil Corp. vs Wyoming Oil and Gas Conservation Commission and Story Oil Impact Committee, 693 p.2d 227, Wyoming 1985) upheld the right of the Commission to work concurrently with the federal government to regulate environmental damage resulting from exploration on federal oil and gas leases. In this case, potential impacts centered on Gulf Oil Corporation's proposed access to the wellsite via a public road through the town of Story. Rather than extend an existing road 3.8 miles up a steep limestone cliff visible from the town of Story, the Commission conditionally approved Gulf's drilling permit application as long as the proposed access route was not used. The Commission concluded that the proposed route would cause unreasonable surface damage to the terrain near Story in violation of Commission rules. It is important to note that while the proposed access road in this case apparently involved a mix of public and private land ownership, the Commission's focus was on preventing environmental damage based on the location of the road as a whole.

TECHNICAL APPENDIX 9
LAND USE

LAND USES IN OIL AND GAS REGIONS

Northern Montana

The shallower reserves in this area result in wells being spaced close together. Typical oil well spacing is one well per 40 acres, and gas wells are usually spaced about one per section of land. Oil wells can be drilled even closer together. The Kevin-Sunburst field supports about nine wells per 40-acre tract.

Access roads in the northern Montana oil fields generally do not require cut-and-fill construction and often are no more than bladed trails. The roads disturb about 1.5 acres per mile and are usually no greater than 1 mile long. Therefore, a typical oil field of five wells would physically occupy about 9 acres, or about 4.5 percent of the land area within a 200-acre field. This amount of disturbance does not constitute a significant loss of grazing land. In northern Montana, livestock grazing use is more commonly limited by poor range conditions or unproductive soils.

Preemption of livestock operations occurs only as maximum density development occurs, such as in the Kevin-Sunburst field. Nine oil wells on a 40-acre tract effectively remove over 25 percent of the available surface area, and the extensive access road network creates problems for livestock control and distribution. The wide well spacing and lack of access roads in a typical gas field result in virtually no impact to rangeland.

Northeastern Montana

Well spacing in the deep petroleum reserves of the Williston Basin is typically one well per 320 acres. Flat terrain and minimal disturbance required for access road blading tend to minimize the amount of land taken out of agricultural production. The average field of three wells will physically occupy only 4 acres with well pads and access roads. Associated tank batteries, oil tanks, and heaters may occupy another 1.5 acres per section, or about 1 percent of the ground surface.

Because of the large volumes of salt water used in drilling, and much larger volumes produced by Williston Basin wells, improper control or handling of the drilling fluids and improper reclamation could adversely affect surface resources such as vegetation and stock water or groundwater (see Water Quality). Produced water or drilling fluid sometimes escapes from the drill pad to the surrounding surface to contaminate soils. The most common source of soil and groundwater degradation around drilling sites has been seepage from the reserve pit (Baker and Brendecke 1983; Murphy and Kehew 1984).

Exploration drilling in the Williston Basin poses a risk that hydrogen sulfide will be encountered. Hydrogen sulfide monitoring, alarm, and evacuation plans should be developed to protect nearby residents.

If successful exploratory drilling leads to field development, the wide spacing between wells will tend to preserve the pastoral quality of the rangeland. The Williston Basin provides most of Montana's petroleum production and the oil industry is familiar in the surroundings of most northeastern Montana residents. Therefore, development of additional fields is not likely to dramatically alter either the rural residential settings or living patterns there.

South, Southcentral, and Southeastern Montana

The common well density in existing oil fields in the central and southcentral regions is about one well per 40 acres. A typical field of four or five wells and associated access trails will occupy 7 to 9 acres, or about 5 percent of the land surface which constitutes an insignificant amount of range removed from the forage base.

Southeastern Montana oil wells generally target a slightly deeper formation, and the wells are correspondingly farther apart (one well per 160 acres). An average field of four wells and associated access trails will occupy about 7 acres in a section of land, or less than 2 percent of the available range. This does not constitute a significant loss of land surface.

ROADS

Montana counties support a network of primary and secondary highways and county roads. Primary and secondary roads are maintained with federal aid funds and county roads by local mill levies. In the oil-producing regions of the state, many of these highways and roads are used by oil and gas traffic to one degree or another. Secondary highways around small towns support commuting drilling crews and well service personnel and equipment. County roads are used for access to the oil and gas fields and may be either paved or gravel surface roads. Gravel surface roads can be maintained by grading and shaping. Unimproved roads generally are single lane and do not have an established roadbed.

Average daily vehicle (ADV) counts on Montana's roads and highways fluctuate seasonally. They generally are highest in the summer months because of tourism and increased agricultural activity. The ADV count is a major determinant of the Level of Service rating, which characterizes a roadway's level of use and typical congestion or delays encountered by motorists using the road. Most of Montana's roads are assigned the two highest categories because the state's population is sparse and congestion and delays are seldom encountered.

Montana law limits the maximum weight of vehicles that may travel the state's roads. Weight limits for primary, secondary, and county roads are the same. The maximum weight is derived by a formula known as the "Bridge Formula," which takes into account the number of axles, the distance between them, and the load on each axle. Generally, vehicles cannot exceed 34,000 lbs. on two axles, or a maximum of 80,000 lbs. on four axles. Vehicles cannot exceed 600 lbs. per inch of tire width.

Vehicles that exceed 80,000 lbs. must receive an operator's permit from the Montana Department of Highways. Permits good for 72 hours cost $20. One-year permits cost $100.

More restrictive weight limits can be applied on specific road sections during the spring thaw (January 15 to May 1). The more restrictive limits are posted on signs along the road. Vehicles are prohibited from exceeding 400 lbs. per inch of tire width on posted sections (Hudson 1988).

TECHNICAL APPENDIX 10
VEGETATION

Table 10-1. Common plant species and topography of Montana vegetation types. Species which distinguish a type are in boldface. Scientific names are listed in Table 10-2.

Vegetation Type	Grassslike	Grasses and Forbs	Shrubs	Trees
1. Alpine Grassland	Ross bentgrass	**Clubmoss**	**Summit willow**	Absent or stunted
Alpine bluegrass	Lupine	**Snow willow**	and scattered.	
Alpine timothy	Indian paintbrush	Red mountainheath		
Sheep fescue	Fringed gentian	Western ledum		
Timber oatgrass	Forget-me-not			
Sedges	Bluebells			
2. Subalpine Forest	**Mountain brome**	Aster	Grouse whortleberry	**Alpine fir**
Idaho fescue	Bluebells	Western ledum	**Engelmann spruce**	
Bentgrass	Lupine	Red mountainheath	**Whitebark pine**	
Bluegrass	Beargrass			
Pine reedgrass	Lewis monkeyflower			
Elk sedge				
Sedges				
Woodrush				
3. Western Larch -Douglas Fir Forest	Sparse	Miscellaneous	Various	**Western larch**
				Douglas fir
4. Lodgepole Pine -Douglas Fir Forest	Pine reedgrass	**Showy aster**	**Big whortleberry**	**Lodgepole pine**
	Elk sedge		**Shinyleaf spirea**	
	Bluegrass		**Rose spirea**	
			Utah honeysuckle	
			Grouse whortleberry	
5. Western Montana Ponderosa Pine Forest	**Pine reedgrass**	Clover	Mallow ninebark	**Ponderosa pine**
	Bluegrass	Arnica	Common snowberry	Rocky Mountain juniper
	Western wheatgrass	Lupine	Oregon grape	
Elk sedge				
Threadleaf sedge				
6. Intermountain Valley Grassland and Meadow	**Meadow grasses**[1]	Scattered	Willow	Absent or occasional
	Sedges			
	Needlegrass			
Cheatgrass brome				
Sandberg bluegrass				
Canada bluegrass				
Prairie junegrass				
Rough fescue				

7. Foothill	Idaho fescue	Rose pussytoes	**Sagebrush**	Absent or
	Blue grama	Douglas phlox	Douglas rabbitbrush	occasional
	Slender wheatgrass	Sulfer wildbuckwheat	Rubber rabbitbrush	
	Needlegrass	Spreading fleabane	Fringed sagewort	
	Prairie junegrass	Ballhead sandwort	Broom snakeweed	
	Canby bluegrass			
	Indian ricegrass			
	Threadleaf sedge			
	Bluebunch wheatgrass			
8. Foothill	**Bluebunch wheatgrass**	Western yarrow	Douglas hawthorne	Quaking aspen
	Western wheatgrass	Clubmoss	Saskatoon serviceberry	
	Idaho fescue	Lupine	Western chokecherry	
	Sheep fescue	Phlox	Russet buffaloberry	
	Needle-and-thread		Rose	
	Mountain brome			
	Pumpelly brome			
	Thickspike wheatgrass			
	Bluegrass			
	Sandberg bluegrass			
	Prairie junegrass			
	Green needlegrass			
	Blue grama			
9. Northern Grassland	Blue grama	**Clubmoss**	Absent or	Absent or
	Western wheatgrass	**Fringed sagewort**	occasional	occasional
	Sedges			
	Needleleaf sedge			
	Needle-and-thread			
	Prairie junegrass			
	Plains reedgrass			
	Threadleaf sedge			
10. Teton River -Judith Basin Grassland	**Sandberg bluegrass**	Fringed sagewort	Absent or	Absent or
	Prairie junegrass		occasional	occasional
	Blue grama			
	Needle-and-thread			
	Western wheatgrass			
	Bluebunch wheatgrass			
	Needleleaf sedge			
	Threadleaf sedge			
11. Missouri Breaks Scrub-Pine	**Plains muhly**	Phlox	Sagebrush	Ponderosa pine
	Bluebunch wheatgrass	Wildbuckwheat	Rabbitbrush	Juniper
	Blue grama		Yucca	
	Western wheatgrass		Plains pricklypear	
	Little bluestem			
	Sandberg bluegrass			
	Threadleaf sedge			

12. Central Grassland	Blue Grama	Fringed sageword	**Sagebrush**	Absent or
	Western wheatgrass	Broom snakeweed	Plains pricklypear	occasional
	Needle-and-thread	Phlox		
	Sandberg bluegrass	Wild buckwheat		
	Green needlegrass	Scarlet globemallow		
	Bluebunch wheatgrass			
	Plains reedgrass			
	Prairie junegrass			
	Plains muhly			
	Threadleaf sedge			
	Needleleaf sedge			
13. Eastern Montana	**Needle-and-thread**	Phlox	Skunkbush sumac	**Ponderosa pine**
Ponderosa Pine	**Blue grama**	Wildbuckwheat	Western snowberry	Rocky Mountain juniper
Forest	**Little bluestem**	Lupine		
	Idaho fescue			
	Western wheatgrass			
	Sandberg bluegrass			
	Prairie junegrass			
	Bluebunch wheatgrass			
	Sideoats grama			
	Threadleaf sedge			
	Needleleaf sedge			
	Bluegrass			
14. Saltbush-	**Thickspike wheatgrass**	**Scurfless saltbush**	**Nuttall saltbush**	Absent or
Sagebrush	**Streambank wheatgrass**	**Biscuitroot**	**Sagebrush**	occasional
	Alkali sacaton	**Nuttall monolepis**	Plains pricklypear	
	Western wheatgrass	**Wild onion**	Black greasewood	
	Blue grama	**Wildbuckwheat**		
	Plains reedgrass	**Scarlet globemallow**		
	Needle-and-thread	Broom snakeweed		
	Sandberg bluegrass			
	Green needlegrass			
	Indian nicegrass			
	Threadleaf sedge			
15. Prairie County	**Needlegrass**	Broom snakeweed	Plains pricklypear	Absent or
Grassland	Sandberg bluegrass	Scarlet globemallow		occasional
	Prairie junegrass	Goosefoot		
	Plains reedgrass			
	Green needlegrass			
	Plains muhly			
	Bluebunch wheatgrass			
	Needleleaf sedge			
	Needle-and-thread			
	Blue grama			

16. Beartooth Juniper-Juniper-Limber Pine	Sandberg bluegrass Needle-and-thread Prairie junegrass Threeawn Threadleaf sedge Blue grama Bluebunch wheatgrass	Miscellaneous	**True mountainmahogny** Skunkbush sumac Common winterfat	**Rocky Mountain juniper** **Limber pine**
17. Ponderosa Pine Savannah	Western wheatgrass Bluebunch wheatgrass Blue grama Sandberg bluegrass Needle-and-thread Little bluestem Buffalograss Priarie junegrass Indian ricegrass Idaho fescue Sideoats grama	Phlox Lupine Wildbuckwheat	Skunkbush sumac Common snowberry Plains pricklypear	**Ponderosa pine** Rocky Mountain juniper
18. Northeastern Grassland	**Little bluestem** Blue grama Needle-and-thread Western wheatgrass Plains muhly Sandberg bluegrass Green needlegrass Threadleaf sedge Needleleaf sedge	Broom snakeweed Fringed sagewort Phlox Scarlet globemallow Woolly plantain Wildbuckwheat	Plains pricklypear Rose Skunkbush sumac Creeping juniper	Absent or occasional
19. Badlands Grassland	Blue grama Western wheatgrass Needle-and-thread Buffalograss Sandberg bluegrass Bluebunch wheatgrass Plains muhly Little bluestem Green needlegrass Prairie sandreed	Broom snakeweed Phlox Wildbuckwheat Scarlet globemallow Goosefoot	**Shadscale saltbush** **Greasewood** Sagebrush Plains pricklypear Silver sagebrush Rabbitbrush Nuttali saltbush Creeping juniper	Absent or ccasional
20. Southeastern Grassland	**Buffalograss** Blue grama Western wheatgrass Threadleaf sedge Sandberg bluegrass Needle-and-thread Thickspike wheatgrass Bluebunch wheatgrass Prairie junegrass	Plantain Scarlet globemallow Wild onion Biscuitroot Fringed sagewort	Big sagebrush Silver sagebrush Nuttall saltbrush Plains pricklypear	Absent or occasional

21. Undifferentiated Stream and Lake	Western wheatgrass Bluegrass Cheatgrass brome Needle-and-thread Blue grama Saltgrass	Goosefoot Sunflower Stickseed Plantain	Rose Sagebrush Silver sagebrush Rabbitbrush Common snowberry Silver buffaloberry	**Cottonwood** **Willow**
22. Sandy Grassland	**Needle-and-thread** **Threadleaf sedge** Bluebunch wheatgrass Indian ricegrass Blue grama Prairie junegrass Sand bluestem Sand dropseed	Breadfoot Scurfpea Scarlet globemallow Purple pointlow	Yucca Rose Silver sagebrush Skunkbush sumac	

[1] Meadow grasses are hairgrass, melic, and bentgrass.

SOURCE: Payne 1973

Table 10-2. Scientific names of plant species listed in Table 10-1.

Common Name	Scientific Name	Common Name	Scientific Name
Arnica	Arnica spp.	Larch, western	Larix occidentalis
Aspen, quaking	Populus tremuloides	Ledum, western	Ledum glandulosum
Aster	Aster spp.	Lupine	Lupinus spp.
Aster, showy	Aster conspicuus	Melic	Melica spp.
Beargrass	Xerophyllum tenax	Monkeyflower, Lewis	Mimulus lewisii
Bentgrass	Agrostis spp.	Monolepis, Nuttall	Monolepis nuttalliana
Bentgrass Ross	Agrostis rossae	Mountainheath, red	Phyllodoce empetriformis
Biscuitroot	Lomantium spp.	Mountainmahogany, true	Cerocarpus montanus
Bluebell	Mertensia sspp.	Muhly, palins	Muhlenbergia cuspidata
Bluegrass	Poa spp.	Neelegrass	Stipa spp.
Bluegrass, alpine	Poa alpina	Needlegrass, green	Stipa viridula
Bluegrass, Canada	Poa compressa	Needle-and-thread	Stipa comata
Bluegrass, Canby	Poa canbyi	Ninebark, mallow	Physocarpus malvaceus
Bluegrass, Sandberg	Poa secunda	Oatgrass, timber	Danthonia intermedia
Bluestem, sand	Andropogon hallii	Onion, wild	Allium spp.
Bluestem, little	Schizachyrium scoparium	Paintbrush, Indian	Castilleja spp.
Brome, cheatgrass	Bromus tectorum	Phlox	Phlox spp.
Brome, mountain	Bromus marginatus	Phlox, Douglas	Phlox douglassii
Brome, pumpelly	Bromux inermis var. pumpellianus	Pine, limber	Pinus flexilis
		Pine, lodgepole	Pinus contorta
Buffaloberry, russet	Shepherdia canadensis	Pine, whitebark	Pinus albicaulis
Buffaloberry, silver	Shepherdia argentea	Pine, ponderosa	Pinus ponderosa
Buffalograss	Buchloe dactyloides	Plantain, woolly	Plantago purshii
Chokecherry, westen	Prunus virginiana	Plantain	Plantago spp.
Clover	Trifolium spp.	Pointloco, purple	Oxytropis lambertii
Clubmoss	Selaginnella spp.	Pricklypear, plains	Opuntia polyacantha
Cottonwood	Populus spp.	Pussytoes, rose	Antennaria rosea
Dropseed, sand	Sporobolus cryptandrus	Rabbitbrush	Chrysothamnus spp.
Fescue, Idaho	Festuca idahoensis	Rabbitbrush, Douglas	Chrysothamnus viscidiflorus
Fescue, sheep	Festuca ovina var. brevifolia	Rabbitbrush, rubber	Chrysothamnus nauseosus
		Reedgrass, plains	Calamagrostis montanensis
Fir, alpine	Abies lasiocarpa	Reedgrass, pine	Calamagrostis rubescens
Fir, Douglas	Pseudotsuga menziesii	Ricegrass, Indian	Oryzopsis hymenoides
Fleabane, spreading	Erigeron divergens	Rose	Rosa spp.
Forget-me-not	Myosotis spp.	Sacaton, alkali	Sporobolus airoides
Gentian, fringed	Gentiana detonsa	Sagebrush	Artemisia spp.
Globemallow, scarlet	Sphaeralcea coccinea	Sagebrush, big	Artemisia tridentata
Goosefoot	Chenopodium album	Sagebrush, silver	Artemisia cana
Grama blue	Bouteloua gracilis	Sagewort, fringed	Artemisia frigida
Grama, sideoats	Bouteloua curtipendula	Saltbush, Nuttall	Atriplex nuttallii
Grape, Oregon	Berberis repens	Saltbush, scurfless	Atriplex diocia
Greasewood, black	Sarcobatus vermiculatus	Saltgrass	Distichlis spp.
Greasewood	Sarcobytus spp.	Sandreed, prairie	Calamovilfa longifolia
Hairgrass	Deschampsia spp.	Sandwort, ballhead	Arenaria congesta
Hawthorn, Douglas	Crataegus douglasii	Scurfpea, breadroot	Psoralea esculenta
Honeysuckle, Utah	Lonicera utahensis	Sedge	Carex spp.
Junegrass, prairie	Koeleria cristata	Sedge, elk	Carex geyeri
Juniper, creeping	Juniperus horizontalis	Sedge, needleleaf	Carex eleocharis
Juniper, Rocky Mtn.	Juniperus scopulorum	Sedge, threadleaf	Carex filifolia

Common Name	Scientific Name	Common Name	Scientific Name
Serviceberry, saskatoon	Amelanchier alnifolia	Wheatgrass, streambank	Agropyron riparium
Snakeweed, broom	Gutierrezia sarothrae	Wheatgrass, thickspike	Agropyron dasystachyum
Snowberry, common	Symphoricarpos albus	Wheatgrass, western	Agropyron smithii
Snowberry, western	Symphoricarpos occidentalis	Whortleberry, big	Vaccinium membranaceum
Spiraea, shinyleaf	Spiraea lucida	Whortleberry, grouse	Vaccinium scoparium
Spiraea, rose	Spiraea rosea	Wildbuckwheat	Eriogonum spp.
Spruce, Engelmann	Picea engelmanni	Wildbuckwheat, sulfur	Eriogonum umbellatum
Stickseed	Lappula spp.	Winterfat, common	Eurotia lanata
Sumac, skunkbush	Rhus trilobata	Willow, snow	Salix nivalis
Sunflower	Helianthus spp.	Willow, summit	Salix saximontana
Threeawn	Aristida spp.	Willow	Salix spp.
Timothy, alpine	Phleum alpinum	Woodrush	Luzula spp.
Wheatgrass, bluebunch	Agropyron spicatum	Yarrow, western	Achillea millefolium
Wheatgrass, slender	Agropyron trachycaulum	Yucca	Yucca spp.

TECHNICAL APPENDIX 11
PUBLIC REVENUES FROM OIL AND GAS DEVELOPMENT

Some information contained in Appendix 11 tables and graphics became available while the EIS was at the printer. For purposes of comparison, dollar values displayed in graphics are adjusted for inflation using 1986 dollars. Dollar values in text and in tables are not adjusted for inflation.

NATURAL RESOURCE TAXES

Severance Taxes

Crude oil recovered from within Montana is subject to a state administered severance tax of 5 percent of the gross value of production. The state's severance tax on natural gas is 2.65 percent of the gross value of production. Figure 11-1 lists severance taxes paid to Montana from the oil and gas industry.

The majority of severance tax collections are allocated to the state's general fund.

One-third of the severance tax revenues allocated to local governments through the state's local government block grant program. A small portion of the revenue also is returned to the local governments where new oil and gas production has occurred (see Figure 11-2).

Oil and gas severance taxes collected by the State of Montana have ranged from $6.6 million in the mid-1970s to over $50 million in the early 1980s. The revenue growth was the result of major increases in the prices of crude oil and slight increases in annual production levels. In 1987, collections were $18.6 million.

In the early 1980s, oil and gas severance taxes accounted for between 11 percent and 13 percent of total Montana Department of Revenue collections compared to 2 percent to 3 percent before the oil boom. In 1987, severance taxes accounted for about 4 percent of the department's collections.

The amount of oil and gas severance taxes collected by the state and reallocated to local governments reflects both changes in prices for crude oil and the volume of new oil and gas discoveries. Lower crude oil prices reduced industry incentives to find new domestic oil fields in the mid-1980s.

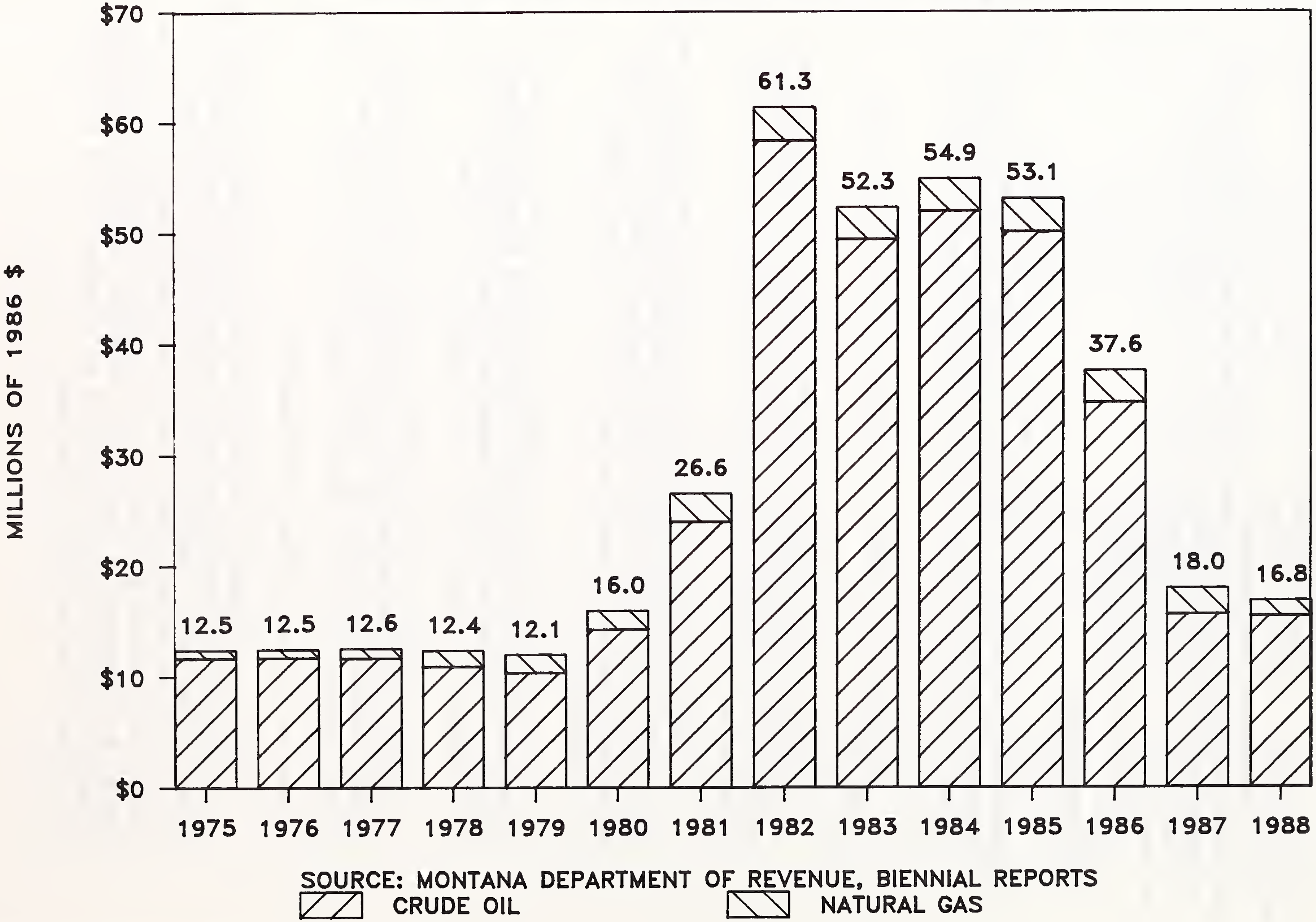
Oil and Gas Producers Privilege and License Tax

The revenues collected by Montana's Oil and Gas Privilege and License Tax are determined by the volumes and market prices of oil and gas produced, stored, and distributed in the state. The tax rate (which cannot be over 2/10 of 1 percent of total values) is set by the Montana Board of Oil and Gas Conservation. Revenue from the tax is used to fund the activities of the Board. Recent increases in annual revenue collections from the tax are mainly a result of a higher tax rate being imposed by the Board. Figure 11-3 shows the amounts of this tax paid in recent years.

FIGURE 11-1

OIL & GAS SEVERANCE TAX COLLECTIONS

BY THE STATE OF MONTANA (MILLIONS OF 1986$)

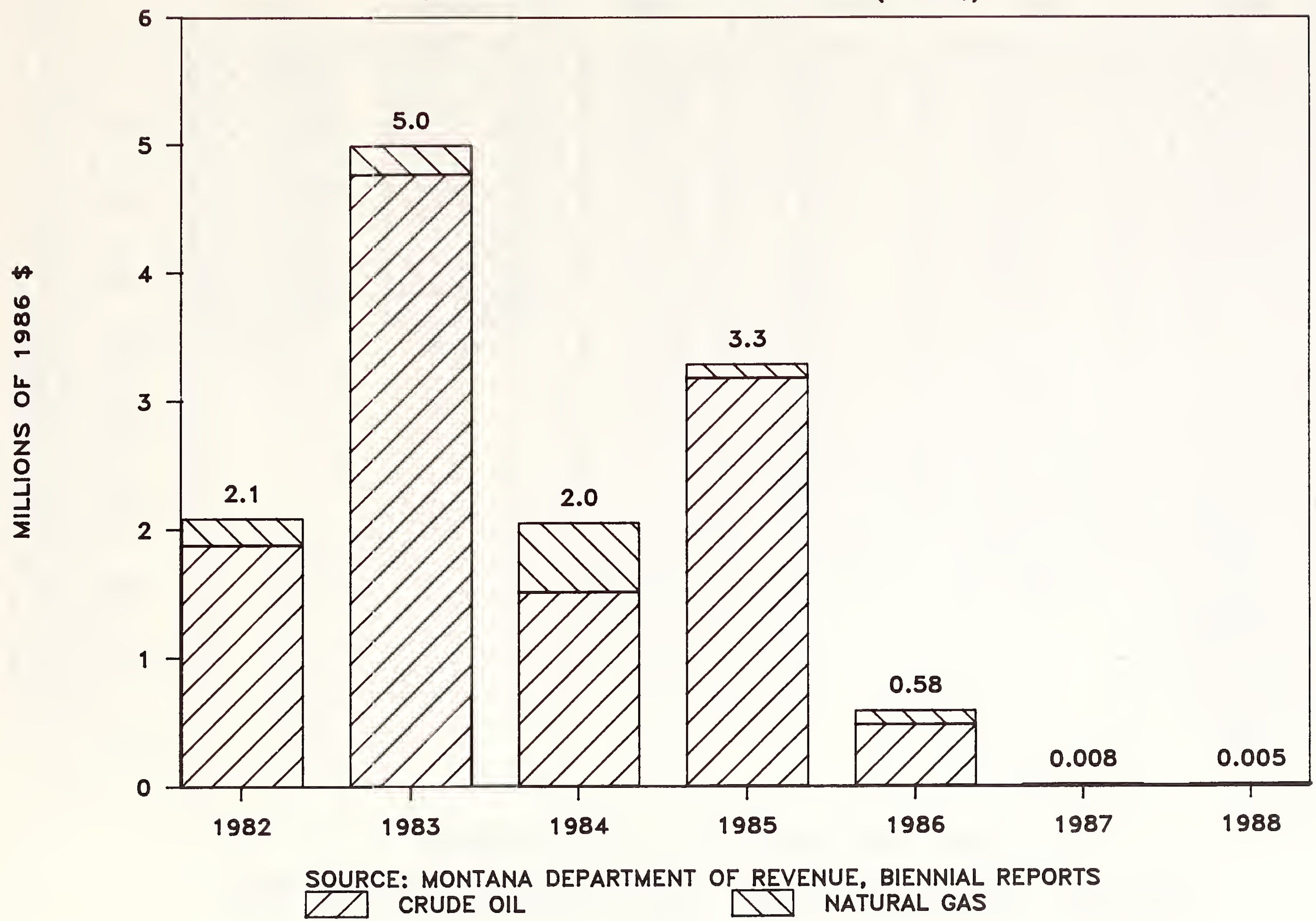


SOURCE: MONTANA DEPARTMENT OF REVENUE, BIENNIAL REPORTS

FIGURE 11-2

MONTANA OIL & GAS SEVERANCE TAXES

RETURNED TO PRODUCING COUNTIES (1986 $)

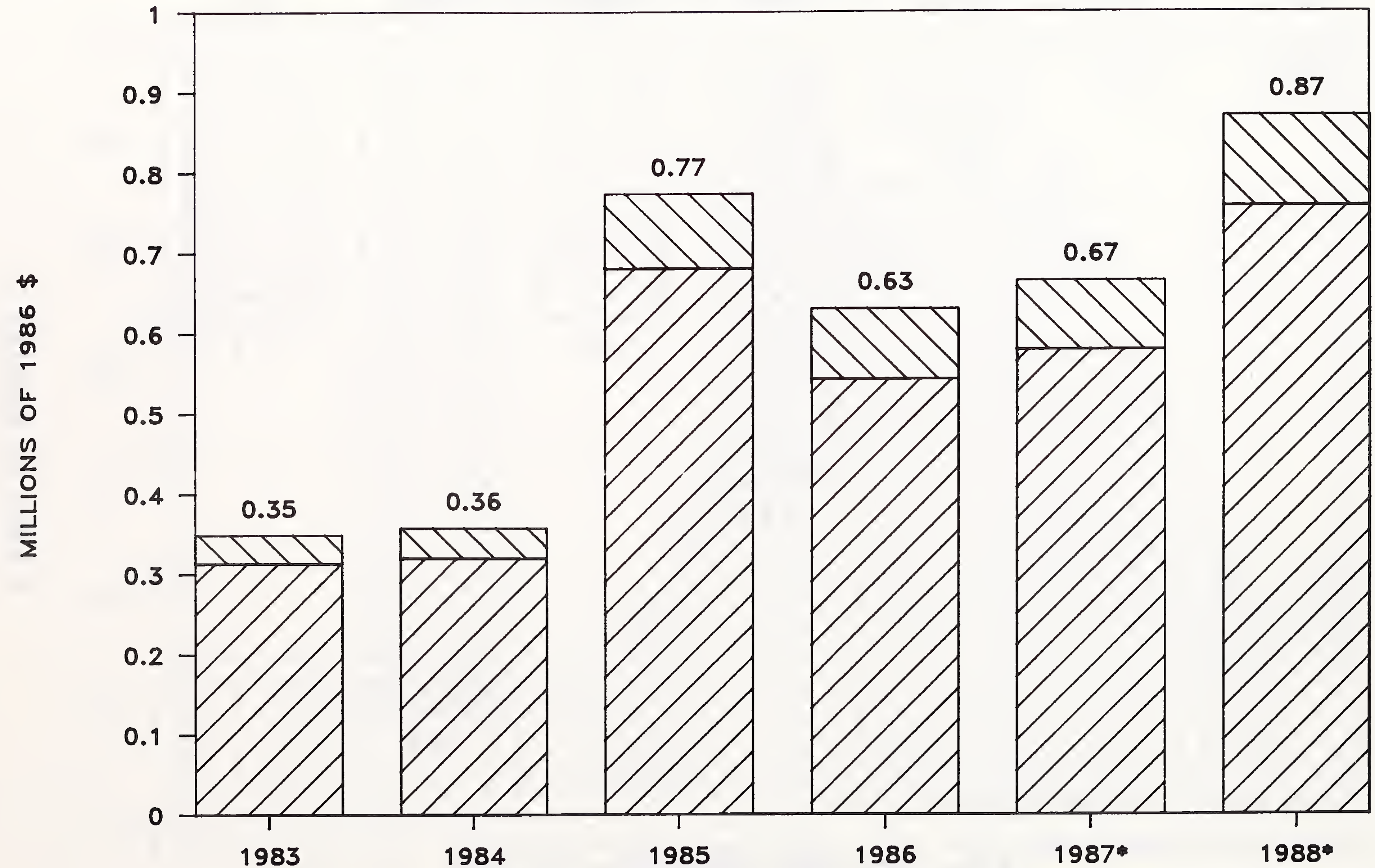


SOURCE: MONTANA DEPARTMENT OF REVENUE, BIENNIAL REPORTS

FIGURE 11-3

OIL & GAS PRIVILEGE AND LICENSE TAXES

MONTANA REVENUE COLLECTIONS 1983 – 1988



SOURCE: MONTANA DEPARTMENT OF REVENUE, BIENNIAL REPORTS

CRUDE OIL   NATURAL GAS

* 1987 and 1988 breakdown of oil and gas taxes are estimates

Resource Indemnity Tax

Montana's Resource Indemnity Trust Fund (RIT) is supported by a state-administered 0.5 percent levy on the gross value of nonrenewable resources produced (extracted) in the state. Crude oil production has been the single greatest source of revenue for the fund. Revenues from the RIT tax are deposited in a trust to protect the state from loss or damage to the environment due to resource development. Interest from the fund is used to finance water development projects and to fund other projects to improve the environment.

Growth in Montana's Resource Indemnity Trust Fund has been substantially enhanced by payments made to the fund by the oil and gas industry. As with other taxes which are determined as a percentage of the value of production, the state's Resource Indemnity Tax collections have fluctuated with the prices of crude oil. Annual collections for the trust fund were greatest in early 1980s and have since been decreasing (see Figure 11-4).

PROPERTY TAXES

The state government, counties, municipalities, local school districts, and special districts levy property taxes against real and personal property. The oil and gas industry, because of the high value of property involved in exploration, development, and production, and the value of oil and gas as commodities, contributes significantly to the property taxes paid in Montana.

The State of Montana uses property taxes to fund a portion of university system operations and as a revenue source for its elementary and high school foundation programs.

The state currently levies 6 mills for university system operations. The foundation programs levy 28 mills for elementary schools and 17 mills for high schools. Essentially, the foundation programs collect and then redistribute property tax revenues to local schools on an equal basis per student.

Local school systems also are funded by county-wide and school district mill levies. The number of mills levied locally varies. Areas containing major oil and natural gas development often have had much lower mill levies than do other areas of the state.

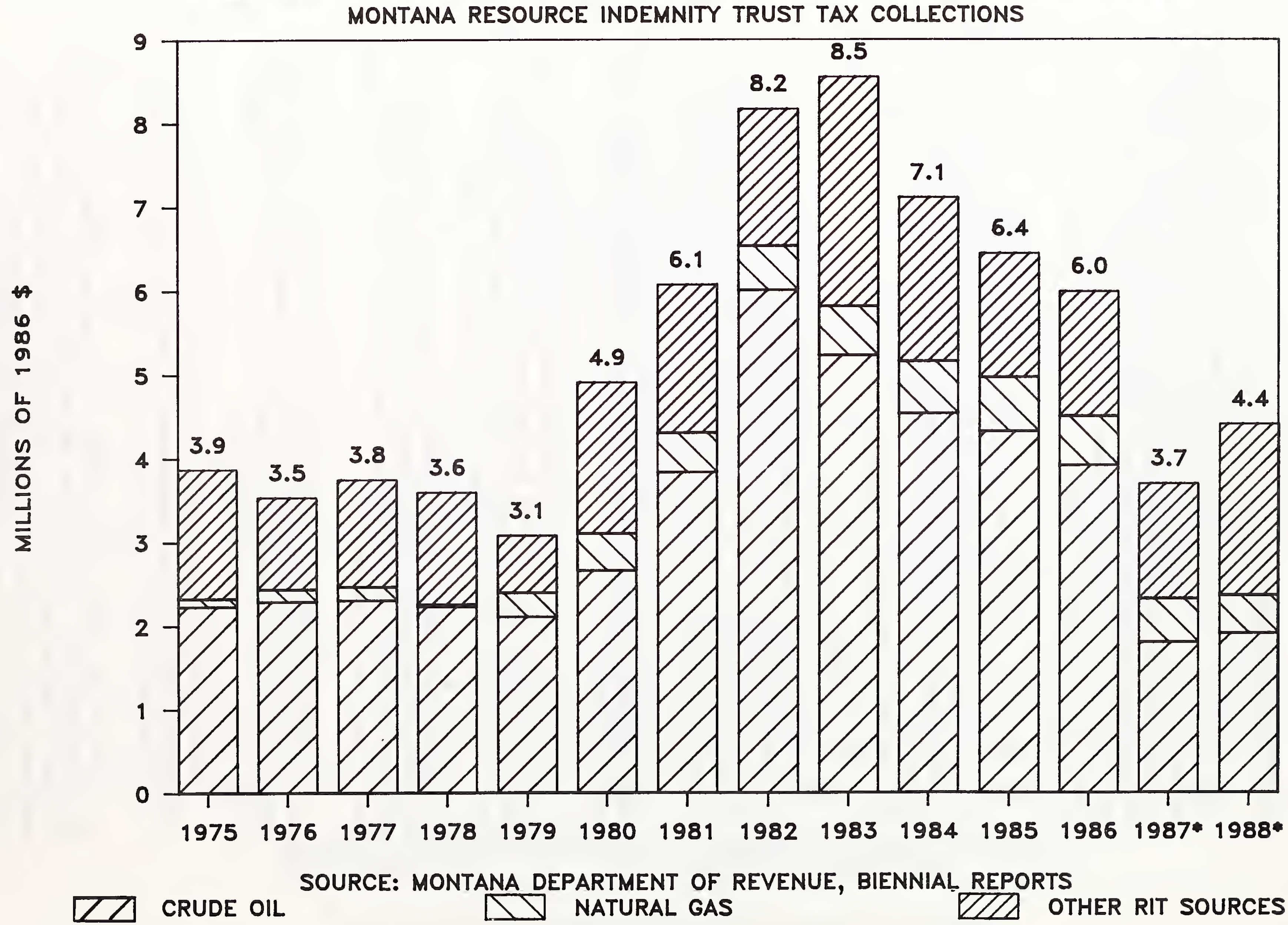
County government and special district levies are applied to the taxable value of property within county or special district boundaries. As with local school levies, counties containing productive oil and gas fields tend to have lower mill levies than most other counties.

Few oil and gas wells are located within the taxing boundaries of incorporated cities and towns, so petroleum production provides little direct tax revenue benefits to municipalities.

Most of the property taxes paid by the oil and gas industry are paid on the net proceeds value of production and on private royalty income. State and local mill levies are applied to the net proceeds values oil and natural gas production, which is determined by subtracting production costs from the gross market values of the oil and gas produced. The levies are also applied to

FIGURE 11-4

OIL, GAS AND OTHER R.I.T. TAX COLLECTIONS



* 1987 and 1988 figures are preliminary estimates

100 percent of the value of the private royalty payments made on oil and gas produced from privately owned mineral rights. Figures 11-5 and 11-6 show the revenue derived from these taxes.

Mill levies are applied to the net proceeds values and royalty payments for the previous year's production.

Role in State Property Tax Base

Oil and gas net proceeds and royalties represent an important but unstable portion of the total property tax base of the State Montana. The dramatic increases and decreases in the value of oil production has resulted in noticeable changes in state's taxable value.

From 1975 to 1982, the taxable value of oil and gas produced in Montana grew from $181 million to $609 million. The percentage of the state's total taxable value attributable to oil and gas production increased from 13 percent to 28 percent. In 1987, the taxable value of production was $252 million, less than 13 percent of the state's total taxable value. Figure 11-7 shows the taxable value of oil and gas production as a percentage of the state's total taxable value.

Role in County and Local Property School Tax Bases

A majority of the taxable value of oil and gas production occurs in a few Montana counties. Historically, county governments and schools in major production areas have had comparatively large tax bases relative to the populations served. With the increases in the prices of crude oil and natural gas during the oil boom, counties and schools in petroleum rich areas experienced a tax base windfall (see tables 11-1 and 11-2).

Though the contribution of oil and gas production to local tax bases has decreased in the mid-1980s, production continues to have a significantly positive impact in oil-producing areas. The per capita and per student taxable valuations continue to be greater in oil and gas producing areas than for most other areas of the state.

In the early 1980s, oil and gas production provided an increasing share of the local tax bases of counties and schools in producing areas. Even with the subsequent declines in the value of production, oil and gas recovery continued to be the predominant segment of local tax bases in most major oil and gas-producing areas.

Role in State Property Tax Revenue Collections

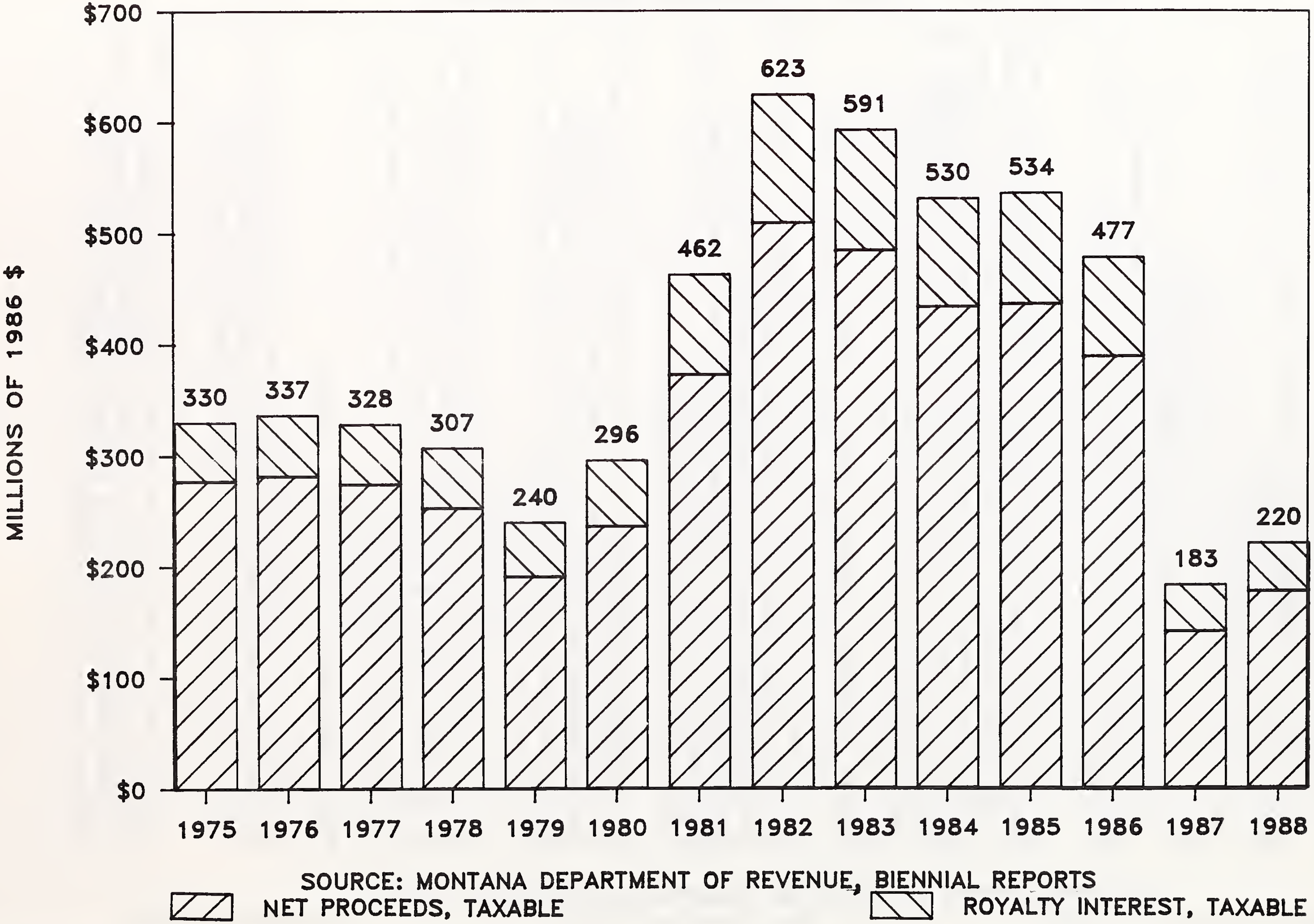
The major fluctuations in the taxable value of oil and gas production has affected the revenue situations of the state's university system and the state's public school foundation programs (see figures 11-8 and 11-9).

The effects of changes in the value of oil and gas production has had a visible influence on the funding of the state's public school foundation programs. Recent reductions in the revenues available to the Foundation Funds for redistribution have contributed to financial problems of local schools throughout Montana (Johnson 1988).

FIGURE 11-5

OIL PROCEEDS AND ROYALTIES - NET TAXABLE VALUE

MONTANA OIL PRODUCTION TOTALS

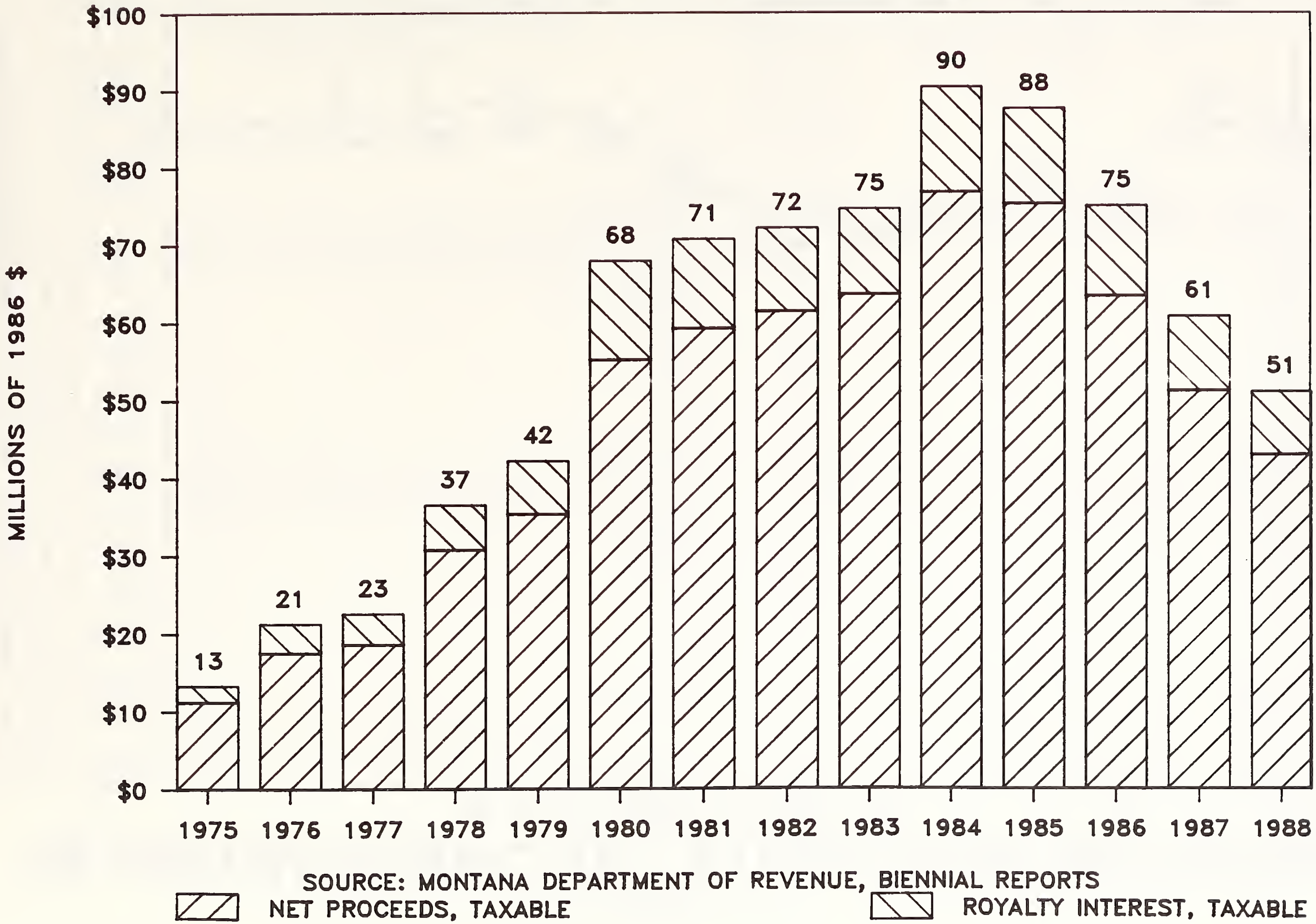


SOURCE: MONTANA DEPARTMENT OF REVENUE, BIENNIAL REPORTS

FIGURE 11-6

GAS PROCEEDS AND ROYALTIES - NET TAXABLE VALUE

MONTANA NATURAL GAS PRODUCTION TOTALS

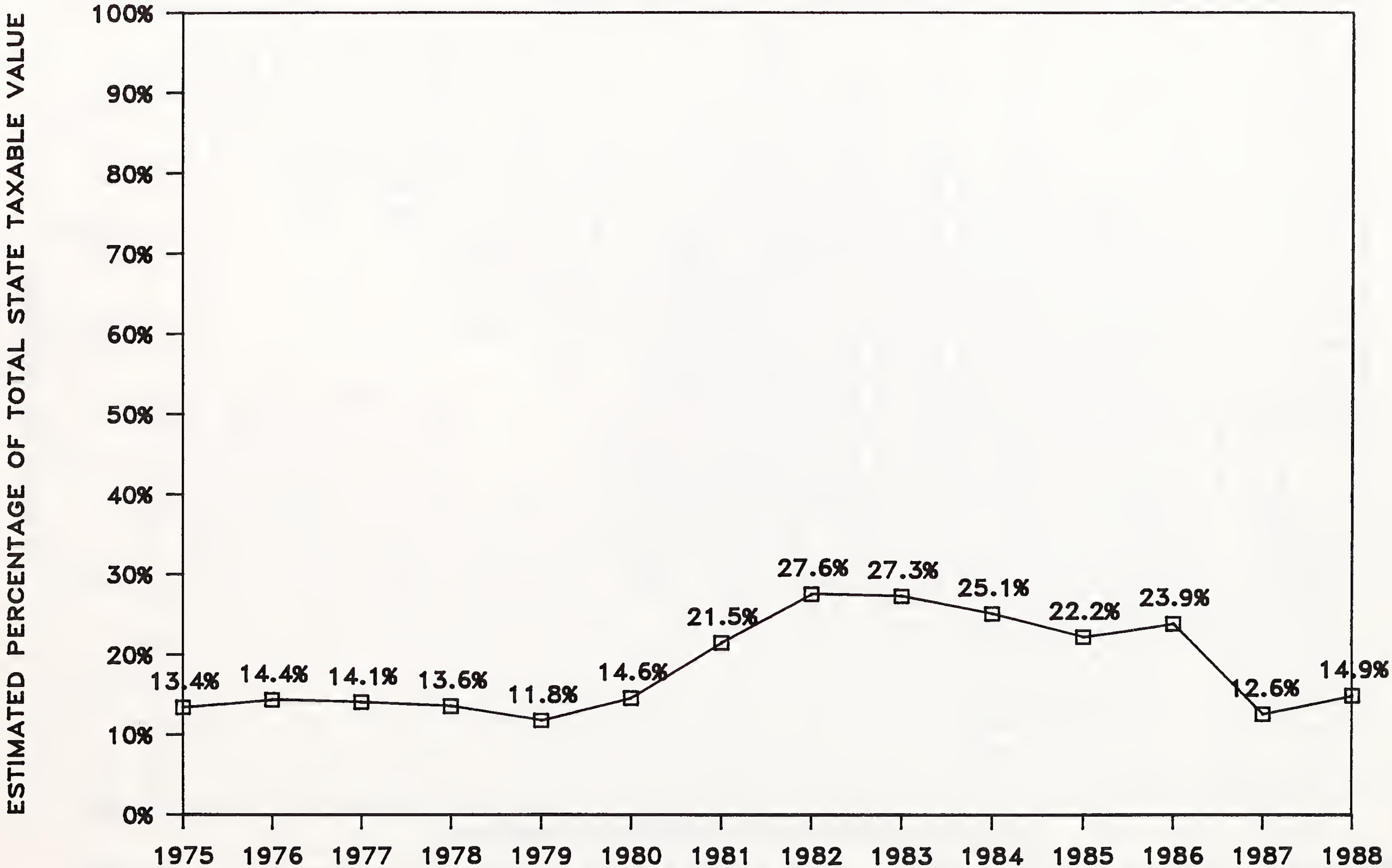


SOURCE: MONTANA DEPARTMENT OF REVENUE, BIENNIAL REPORTS

FIGURE 11-7

OIL AND GAS PRODUCTION TAXABLE VALUE PERCENTAGE

OF TOTAL STATEWIDE TAXABLE VALUE



SOURCE: MONTANA DEPARTMENT OF REVENUE, BIENNIAL REPORTS

Table 11-1. Taxable Value of Oil and Natural Gas Production for Selected Oil and Natural Gas-Producing Counties 1977, 1982, 1987 (in $1 million).

	1977 Taxable Value	1982Taxable Value	1987 Taxable Value
Blaine	$ 5.6	$ 19.0	$ 18.4
Carbon	5.1	11.8	7.7
Fallon	28.2	104.1	51.8
Glacier	16.4	27.0	11.7
Hill	3.5	11.9	10.7
Liberty	3.3	11.3	4.7
Musselshell	8.2	21.6	6.6
Pondera	2.2	12.5	2.9
Phillips	0.4	7.1	2.5
Powder River	58.5	61.4	9.3
Richland	14.2	113.4	30.3
Roosevelt	7.1	38.0	15.1
Rosebud[1]	18.6	22.8	3.3
Sheridan	7.6	77.2	22.7
Toole	7.0	60.1	12.0
Wibaux	3.6	22.7	9.2
Statewide Total:	$206.4	609.1	243.1

[1] Rosebud County's tax base includes major coal mines and electrical generating plants.

Table 11-2. Taxable Value of Oil and Natural Gas Production as a Percent of Total Taxable Value for Selected Oil and Natural Gas-Producing Counties 1977, 1982, 1987.

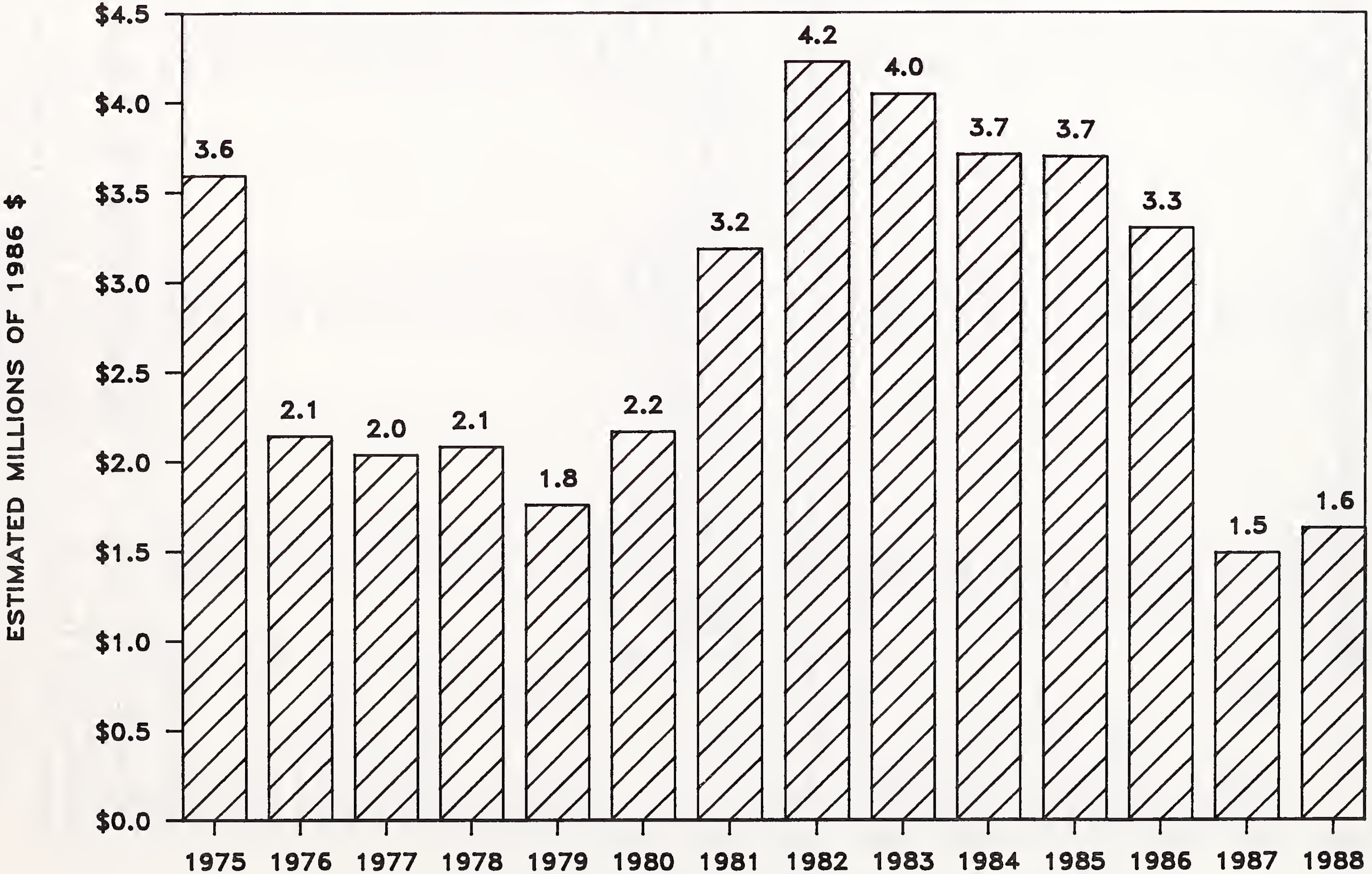
	1977 Percent of Taxable Value	1982 Percent of Taxable Value	1987 Percent of Taxable Value
Blaine	28.9%	56.7%	55.8%
Carbon	25.8%	43.4%	31.9%
Fallon	74.2%	88.0%	80.1%
Glacier	52.3%	60.0%	37.2%
Hill	11.7%	26.3%	24.6%
Liberty	29.0%	52.6%	33.0%
Musselshell	50.2%	76.3%	46.2%
Pondera	11.1%	38.1%	39.4%
Phillips	3.2%	29.9%	13.7%
Powder River	76.8%	84.0%	56.3%
Richland	41.3%	78.4%	50.0%
Roosevelt	30.9%	56.9%	33.4%
Rosebud[1]	21.5%	13.9%	1.5%
Sheridan	40.5%	83.6%	59.6%
Toole	31.1%	60.1%	38.2%
Wibaux	43.8%	78.4%	64.7%
Statewide Total:	14.1%	27.6%	12.5%

[1] Rosebud County's tax base includes major coal mines and electrical generating plants.
Table developed from information published in Montana Department of Revenue Biennial Reports and information updates provided by the Department.

FIGURE 11-8

PROPERTY TAXES PAID ON OIL AND GAS PRODUCTION

TO FUND THE MONTANA UNIVERSITY SYSTEM*

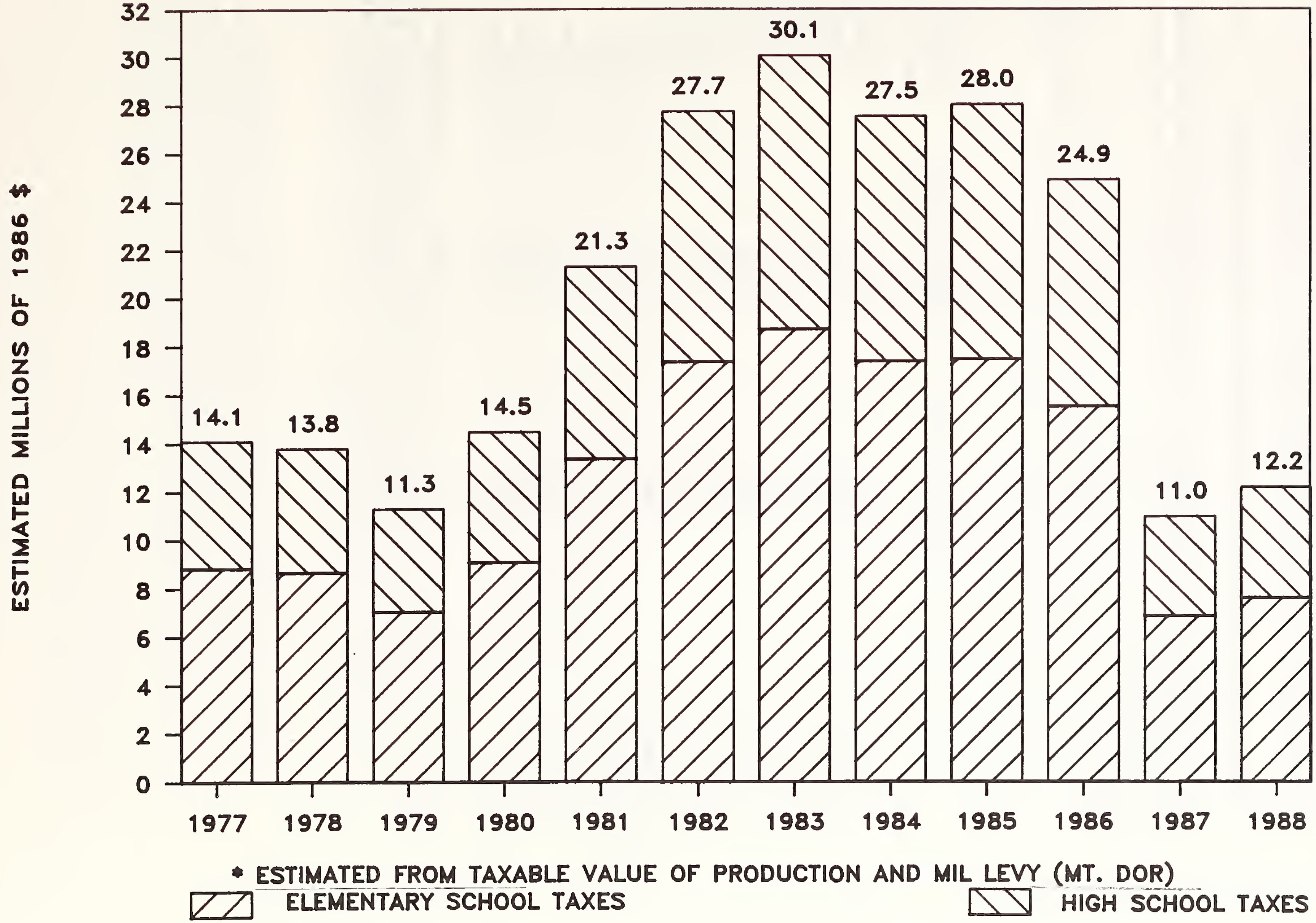


* ESTIMATED FROM PRODUCTION TAX VALUES AND UNIVERSITY MIL LEVY (MT. DOR)

FIGURE 11-9

PROPERTY TAXES PAID ON OIL AND GAS PRODUCTION

TO FUND ELEMENTARY/ HIGH SCHOOL FOUNDATION PROGRAMS*



* ESTIMATED FROM TAXABLE VALUE OF PRODUCTION AND MIL LEVY (MT. DOR)

Taxes paid into the Foundation Fund are collected by county governments and only surplus revenues are actually transferred to the state for redistribution.

Role in County and Local School Property Tax Revenue Collections

County government and local school property tax revenues derived from oil and gas production grew substantially in the 1970s and early 1980s (see tables 11-3 and 11-4).

Table 11-3. Estimated County Government Property Taxes Paid on Oil and Gas Production for Selected Oil and Natural Gas-Producing Counties 1977, 1982, 1987 (in $1 million).

	1977 Property Taxes Paid	1982 Property Taxes Paid	1987 Property Taxes Paid
Blaine	$ 0.325	$ 1.181	$ 0.960
Carbon	0.273	0.509	0.414
Fallon	1.015	2.706	1.139
Glacier	0.622	1.537	0.804
Hill	0.183	0.601	0.675
Liberty	0.193	0.599	0.260
Musselshell	0.180	0.561	0.419
Pondera	0.118	0.383	0.239
Phillips	0.025	0.502	0.579
Powder River	1.988	1.474	0.549
Richland	0.456	2.949	1.153
Roosevelt	0.311	1.215	0.664
Rosebud	0.316	0.410	0.036
Sheridan	0.280	2.471	0.726
Toole	0.456	1.767	0.493
Wibaux	0.195	0.795	0.450
Statewide Total:	$ 7.800	$20.800	$10.500

NOTE: Table based on historical mill levy and taxable valuation information contained in Biennial Reports of the Montana Department of Revenue.

Table 11-4. Estimated School Property Taxes Paid on Oil and Gas Production for Selected Oil and Natural Gas-Producing Counties 1977, 1982, 1987 (in $1 million). (Dollar values not adjusted for inflation.)

	1977 Property Taxes Paid	1982 Property Taxes Paid	1987 Property Taxes Paid
Blaine	$ 0.151	$ 0.666	$ 1.311
Carbon	0.238	0.628	0.737
Fallon	0.310	0.833	2.277
Glacier	0.573	1.726	1.503
Hill	0.242	1.025	1.468
Liberty	0.183	0.260	0.355
Musselshell	0.163	0.734	0.563
Pondera	0.086	0.411	0.978
Phillips	0.015	0.402	0.306
Powder River	0.409	0.798	0.679
Richland	0.484	3.062	1.851
Roosevelt	0.367	1.481	0.287
Rosebud	0.242	0.479	0.125
Sheridan	0.288	1.081	1.587
Toole	0.196	0.979	0.866
Wibaux	0.170	0.432	0.386
Statewide Total:	$ 4.800	$16.200	$16.800

NOTE: Estimates for local school tax revenues are only for county and local district levies. Revenues resulting from statewide foundation fund levies are presented in Figure 11-8. Revenue estimates calculated from taxable value information for production and average mill levy information reported by the Department of Revenue and the Montana Department of Commerce. Estimates should be viewed only as general indicators of taxes paid by the oil and gas industry.

The unanticipated decreases in the taxable values of oil and gas production have created fiscal difficulties for counties and schools. Problems associated with decreases in local tax bases have in some instances been compounded by the effects of the 1986 Montana Ballot Initiative 105, which restricts the abilities of local governments and schools to raise mill levies.

When inflation is accounted for, total county government revenues from oil and gas net proceeds and royalty taxes in 1987 were estimated to be 57 percent less than in 1982 and 23 percent less than in 1977. Inflation adjusted local school tax revenues (exclusive of foundation fund levies) were estimated to be 12 percent lower than in 1982, but about double total production tax revenues received in 1977.

Real Property and Equipment of the Industry

The real property and business operations property of the oil and gas extraction industry also are subject to property tax levies. The extraction industry pays property taxes on the land and buildings it owns. State and local mill levies are applied to 3.86 percent of the market values of land and buildings owned by the oil and gas industry. The taxable value of equipment and machinery used in extraction is generally 11 percent of market values.

Property taxes paid by the oil and gas industry on land and buildings, and property taxes paid on equipment and machinery used in oil and gas exploration and development are substantial, but cannot be quantified.

In counties where the oil and gas industry had a high level of activity, the taxable value of Class 8 property, manufacturing and mining machinery (which includes oil and gas extraction equipment and machinery), is notably greater than for most other counties. Because much of the equipment used in oil and gas extraction activities is mobile, increases and decreases in exploration activity has resulted in taxable property being moved on and off of state and local tax bases.

Other Real Property and Personal Property

Especially in northeastern Montana, the population and economic growth spurred by the boom in oil and gas activity resulted in substantial new housing and commercial business development. In addition, strong market demand increased the values of preexisting housing and business property (Haugen 1988). The new development and increases in the values of preexisting property resulted in corresponding increases in the taxable values of residential and commercial property in municipalities, counties, and school districts in the region. The out-migration and lower levels of economic activity occurring during the ensuing "bust" resulted in decreases in the taxable values of residential and commercial property in northeastern Montana. In some areas, state appraisers have lowered the taxable values of real property to reflect current market values. For example, the city of Sidney recently experienced a 14 percent reduction in its total taxable valuation as a result of a reassessment of real property. Many mobile homes, a substantial portion of the region's new housing stock during the boom, have been relocated elsewhere also contributing a loss of tax base (Mercer 1988).

INCOME TAXES

Corporate License and Income Taxes

Montana's Corporate Income and License Tax is an income tax paid by corporations operating in the state. Montana's corporate income tax rate is 6 3/4 percent of net income (gross income minus allowable deductions). Corporation income tax revenues paid to the state are allocated in the following manner: 64 percent to the General Fund; 25 percent to the School Foundation Program; and 11 percent to the state's Long Range Building Program.

Corporation taxable income appears to have been notably influenced by the market prices of crude oil. Corporation License and Income Taxes paid by the oil and gas industry followed the growth and decline in the gross values of

in-state oil and gas production. State corporate income tax receipts from the oil and gas industry were greatest from 1981 to 1983 and have since decreased. See Table 11-5 and Figure 11-10.

Table 11-5. Corporate License Taxes Paid by the Oil and Gas Industry 1979-1988 (in $1,000s).

	Taxes Paid by Oil and Gas Corporations[1]	All Corporate Income Taxes Paid to State[2]	Percent of Corporation Tax Paid by Oil and Gas Industry
1979	$ 4.6	$36.1	12.9%
1980	4.9	45.6	11.8%
1981	7.7	52.9	14.5%
1982	9.9	44.6	22.3%
1983	9.4	35.8	26.1%
1984	5.5	35.3	15.6%
1985	6.6	62.7	10.5%
1986	6.5	58.5	11.1%
1987	4.0	34.6	11.6%
1988	1.3	46.2	2.81

Sources:
1 Research Bureau,Montana Department of Revenue, Computer Tape, Corporation Income Taxes by SIC Code, 1988.
2 Montana Department of Revenue, Report of the Montana Department of Revenue: Biennial Reports. 1976-1988.

Table 11-5 overstates the corporate income taxes paid exclusively by the oil and gas extraction industry. The corporate income taxes depicted in the above table include taxes paid by corporations conducting refining activities and other activities not directly associated with oil and gas extraction. It is clear from the table that tax collections from oil and gas corporations were greatest during the peak years of the oil boom, suggesting that extraction activities contributed integrally to the corporation taxes paid during this period.

Personal Income Taxes

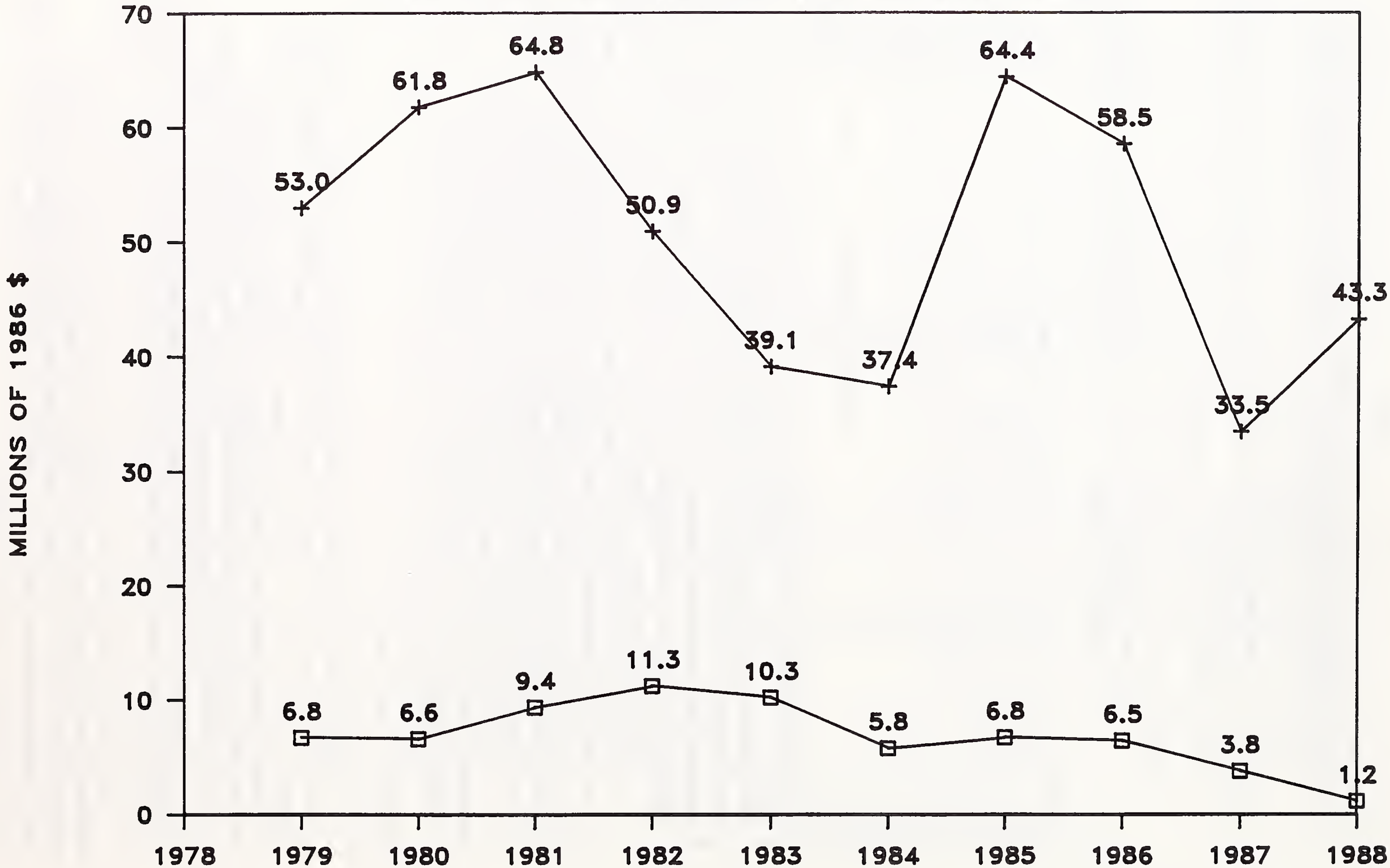
Personal income taxes are the single greatest source of state government revenue collections. The rates for Montana's personal income tax range from 2 percent to 11 percent. Earnings of persons working in the oil and gas extraction industry and the income accruing to persons having royalty interests in production from Montana oil and gas wells contribute importantly to personal income tax payments collected by the State of Montana. The state's apportionment of personal income tax collections are the same as for corporation license and income tax revenue (see Table 11-6 and Figure 11-11).

Average incomes (and tax liabilities to the state) for persons working Montana's oil and gas extraction industry are consistently above average. However, the number of persons working in the industry varies markedly. As a result, state income tax revenues received from persons working in the industry fluctuate from year to year.

FIGURE 11-10

CORPORATE LICENSE TAXES

PAID BY THE O & G INDUSTRY AND ALL CORPORATIONS



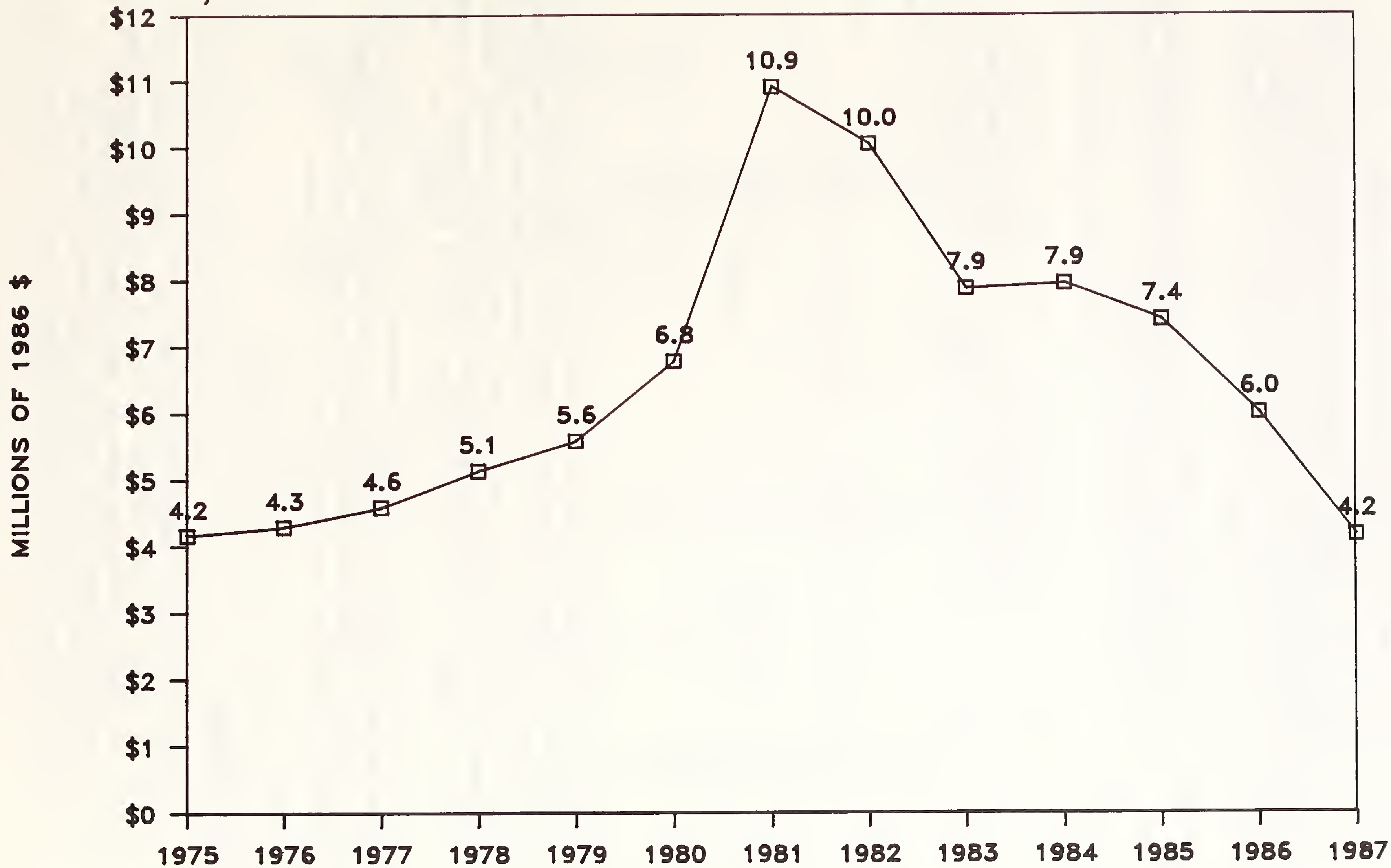
SOURCE: MONTANA DEPARTMENT OF REVENUE, BIENNIAL REPORTS

□ O & G INDUSTRY + ALL CORPORATIONS

FIGURE 11-11

ESTIMATED TOTAL PERSONAL INCOME TAXES PAID

by PERSONS WORKING IN OIL AND GAS EXTRACTION INDUSTRY & ON ROYALTY INCOME



SOURCES: U.S. Bureau of Economic Analysis, MT. Dept. Labor & Industry, MT. Dept. of Revenue

□ ESTIMATED TOTAL PERSONAL INCOME TAXES

Private royalty incomes also vary from year to year due to changes in production levels and in the prices of crude oil and natural gas.

In 1981, State of Montana tax collections from persons working or having interests in oil and gas extraction (wage and salary and other labor and proprietor earnings, plus royalty interests) are estimated to have been about $9 million. Oil and gas related income is estimated to account for about 6 percent of the state's total personal income tax collections.

Table 11-6. Estimated Personal Income Taxes from Persons Working in Oil and Gas Extraction Industry and Persons Receiving Oil and Gas Royalty Income 1976-1987 (in $1 million).

	Estimated Personal Income Taxes on Oil and Gas Related Income	Percent of Total State Income Tax Tax Collections
1975	$2.2	2.5%
1976	2.4	2.4%
1977	2.7	2.4%.
1978	3.2	2.6%
1979	3.8	2.7%
1980	5.0	4.2%
1981	8.9	6.1%
1982	8.8	6.1%
1983	7.2	4.9%
1984	7.5	4.2%
1985	7.2	4.0%
1986	6.0	3.5%
1987	4.3	2.2%

* Estimates developed by applying average annual deductions and tax rates to estimates of annual oil and gas related wage, salary and proprietor earnings and royalty income. Persons receiving occupational and royalty income from the oil and gas industry tend to have above average incomes. Because Montana income tax rates increase with income, the use of average tax rates may cause the table to understate the taxes paid on oil- and gas-related income.

The mid-1980s decline in Montana's estimated income tax collections from persons deriving income from the oil and gas extraction industry is the result of the loss of a substantial number of jobs in the industry and the major reductions in royalty payments received by royalty interest owners.

LEASE PAYMENTS AND ROYALTY INCOME

Lease Payments

Oil and gas firms bid competitively for the right to develop mineral rights owned by the State of Montana. Payments to the state include a bonus payment, an annual per-acre lease payment, and an annual penalty payment, which is made if the lessee fails to carry out exploratory drilling within five years.

Leases are awarded for 10 years. The amount of the bonus payment bid serves as the basis upon which leases are awarded. Bonus payments vary widely, depending on the level of competition for a leasing area. Annual lease payments and penalty payments are fixed. Annual lease payments are currently $1.50 per acre. Annual penalty payments range from $1.25 per acre to $2.50 per acre.

Over 90 percent of lease revenues accruing to the state are assigned to Montana's public school foundation programs. The university system also receives revenues for oil and gas industry payments for exploration and development rights to state lands, as do the Montana School for the Deaf and Blind and the state's Pine Hills School.

At the peak of the oil boom, frenzied competition for leases greatly increased amounts of bonus payments. In 1981, annual bonus, lease, and nondrilling payments to the state exceeded $38 million. With the lower crude oil prices of the mid-1980s, competition for leases has waned and bonus payment revenues dwindled. In 1987, the state received about $5 million in payments (see Table 11-7 and Figure 11-12).

Table 11-7. State of Montana Income from the Lease of State Lands for Oil and Natural Gas Development 1976-1988 (in $1 million).

	Lease and Bonus Payments[1]		Nondrilling Payments	Total Payments
1976	$ 2.5		$ 0.5	$ 3.1
1977	3.0		0.5	3.5
1978	5.5		0.9	5.5
1979	6.6		1.1	7.7
1980	12.4		1.2	13.6
1981	37.4		1.4	38.8
1982	18.1		1.7	19.8
1983	8.6		1.7	10.3
	Lease Payments Only[2]	Bonus Payments Only[2]		
1984	$ 5.7	$ 5.1	$ 2.4	$13.2
1985	5.2	2.0	3.4	10.5
1986	4.2	0.8	3.2	8.2
1987	2.9	0.2	2.0	5.1
1988	2.3	0.2	1.5	4.6

1 Prior to 1983, state collections of bonus and lease payments are combined.
2 From 1983 on, bonus and lease payment collections are presented separately.
Source: Alan Christianson, Montana Department of State Lands 1988.

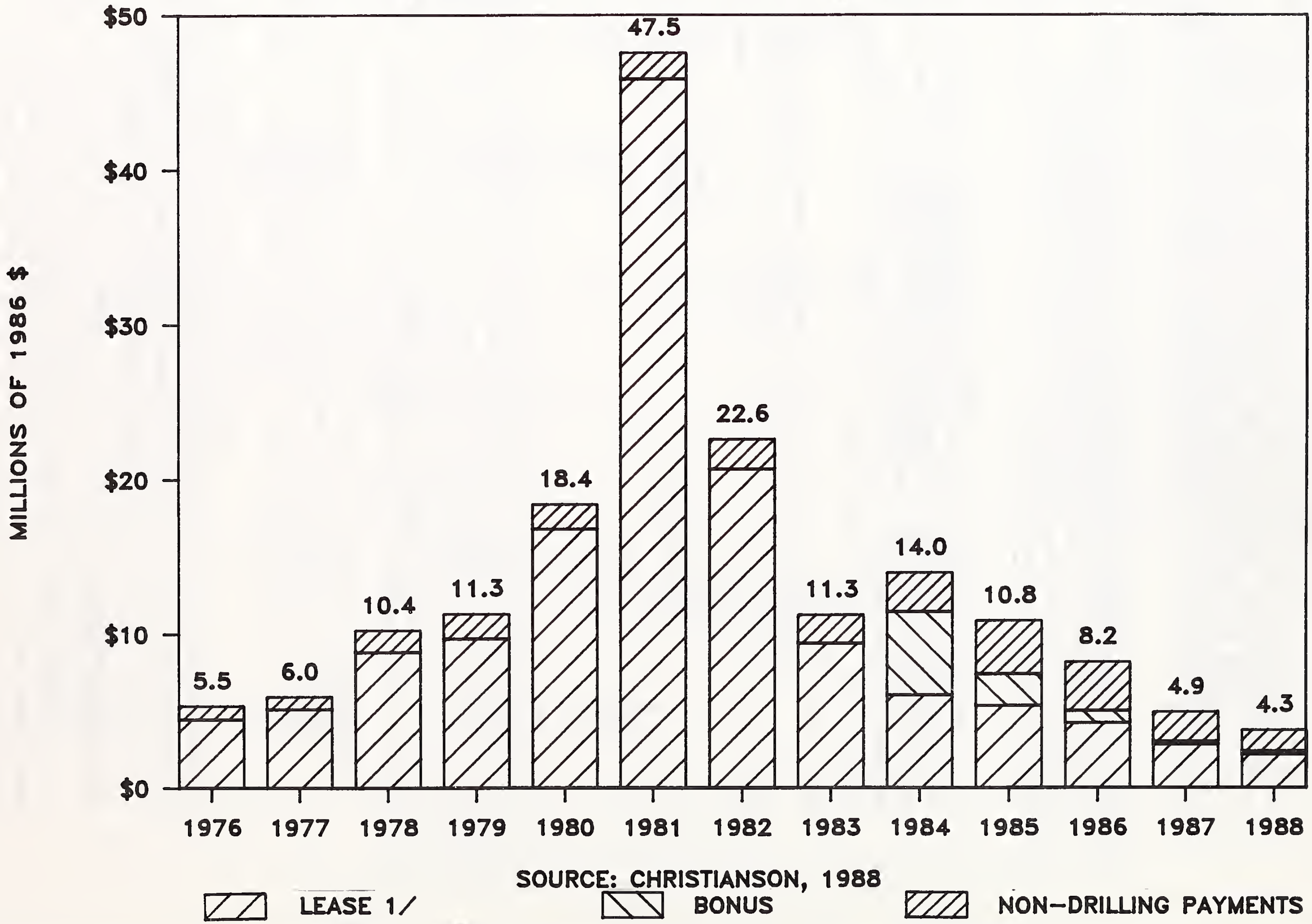
State Royalty Payments

Collections from the oil and gas industry historically have been the state's largest single source of royalty income from mineral development on state-owned lands. Typically, oil and gas production has accounted for 70

FIGURE 11-12

STATE OF MONTANA LEASE PAYMENT INCOME

from the LEASE OF STATE LANDS FOR OIL & GAS DEVELOPMENT



SOURCE: CHRISTIANSON, 1988

1/ Prior to 1984, lease and bonus collections are combined.

percent to 90 percent of state royalty income resulting from mineral production on state lands.

Predictably, royalty payments to Montana peaked at the pinnacle of oil prices in the early 1980s. Between 1976 and 1981, the state's annual royalty income from the payments of oil and gas industry grew from about $3 million to over $11 million. The growth in oil and gas royalty income was of particular benefit to Montana's elementary and high schools. Royalty payments contributed to increases in the principal of the Common School Permanent Trust Fund, which expanded the fund's interest earnings and, consequently, the monies redistributed to schools through the public school foundation programs. Units of the Montana University system and special state operated schools also benefited from increases in royalty payments to trust funds (see Table 11-8 and Figure 11-13).

Table 11-8. Montana Royalty Income from Oil and Natural Gas Production from State-Owned Mineral Rights (in $1,000s).

	Oil and Gas Royalty Payments to the State		Total Royalty Payments to the State from Mineral Leases	Percent of Total State Royalties from Oil and Gas Production
1976	$ 2.1		$ 2.8	73%
1977	2.4		3.3	71%
1978	3.0		4.0	75%
	Oil Royalties Only[2]	Gas Royalties Only[2]		
1979	$ 2.4	$0.5	$ 4.1	70%
1980	3.6	0.6	5.8	73%
1981	8.2	1.3	11.0	86%
1982	7.0	1.0	8.9	91%
1983	6.5	1.0	8.7	87%
1984	6.0	1.3	8.3	88%
1985	5.1	1.4	8.2	79%
1986	4.2	1.2	6.2	88%
1987	2.4	1.9	5.7	58%
1988	2.6	0.9	6.3	55%

1 Prior to 1979, state collections of oil and gas royalty payments are combined.
2 From 1979 on, oil and gas royalty payments are presented separately.
Source: Alan Christianson, Montana Department of State Lands 1988.

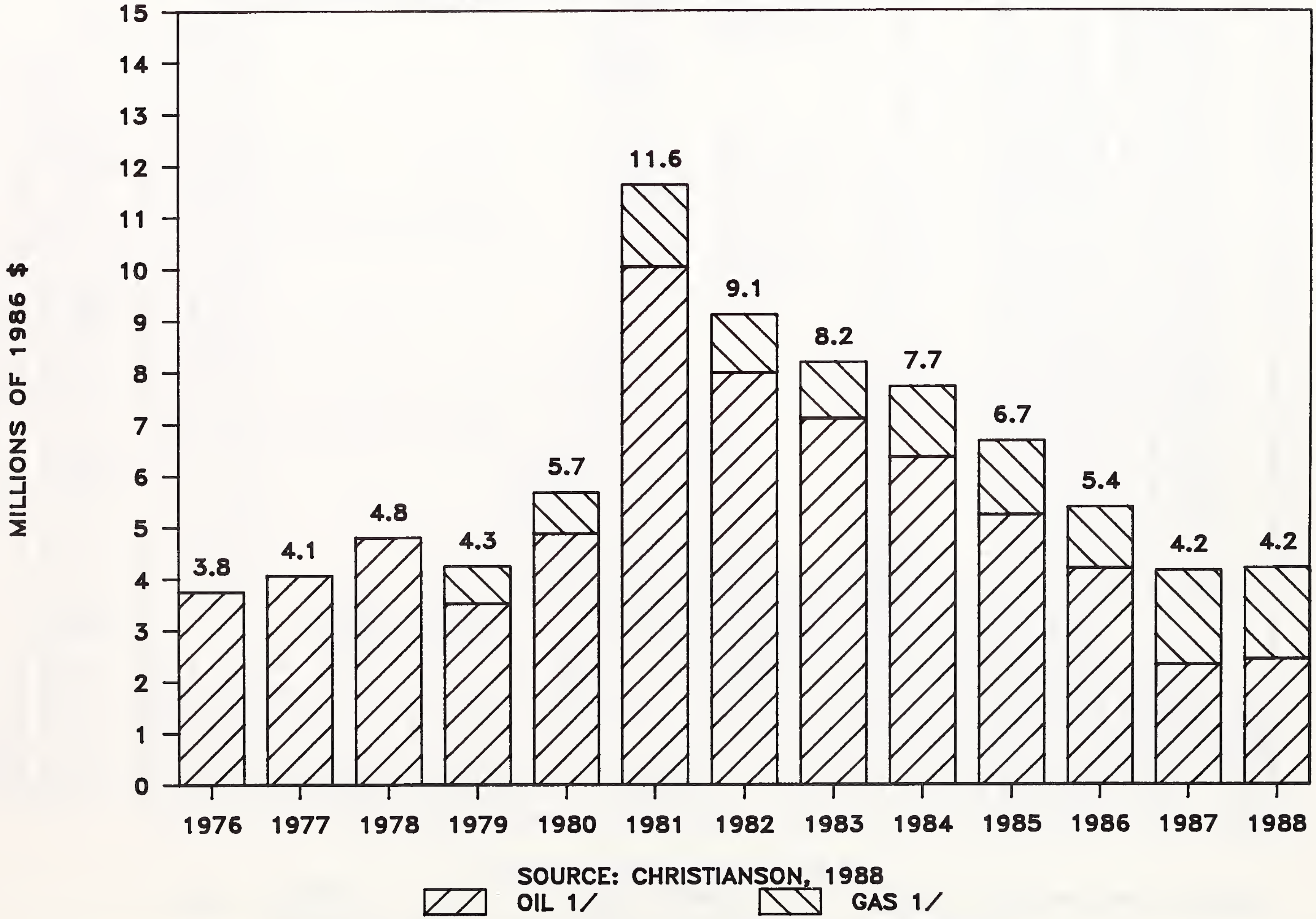
Federal Royalty Payments

The State of Montana receives about one half of the royalty and other collections received by the federal government as a result of oil and gas leasing and production from federally owned mineral rights. Income from federal payments is allocated to the elementary and high school foundation programs.

FIGURE 11-13

MONTANA STATE LANDS ROYALTY INCOME

from OIL AND GAS PRODUCTION from STATE MINERAL RIGHTS



SOURCE: CHRISTIANSON, 1988

1/ Prior to 1979, oil and gas royalties are combined.

Montana's share of federal collections has generally paralleled its income from state owned lands. State receipts increased rapidly in the 1970s and early 1980s. Receipts have been lower in the latter 1980s (see Table 11-9 and Figure 11-14). Table 11-9 and Figure 11-14 do not include Montana's share of lease, bonus, and other payments made to the federal government.

Table 11-9. Estimated Montana Royalty Income from Oil and Natural Gas Production from Federally Owned Mineral Rights (in $1,000s).

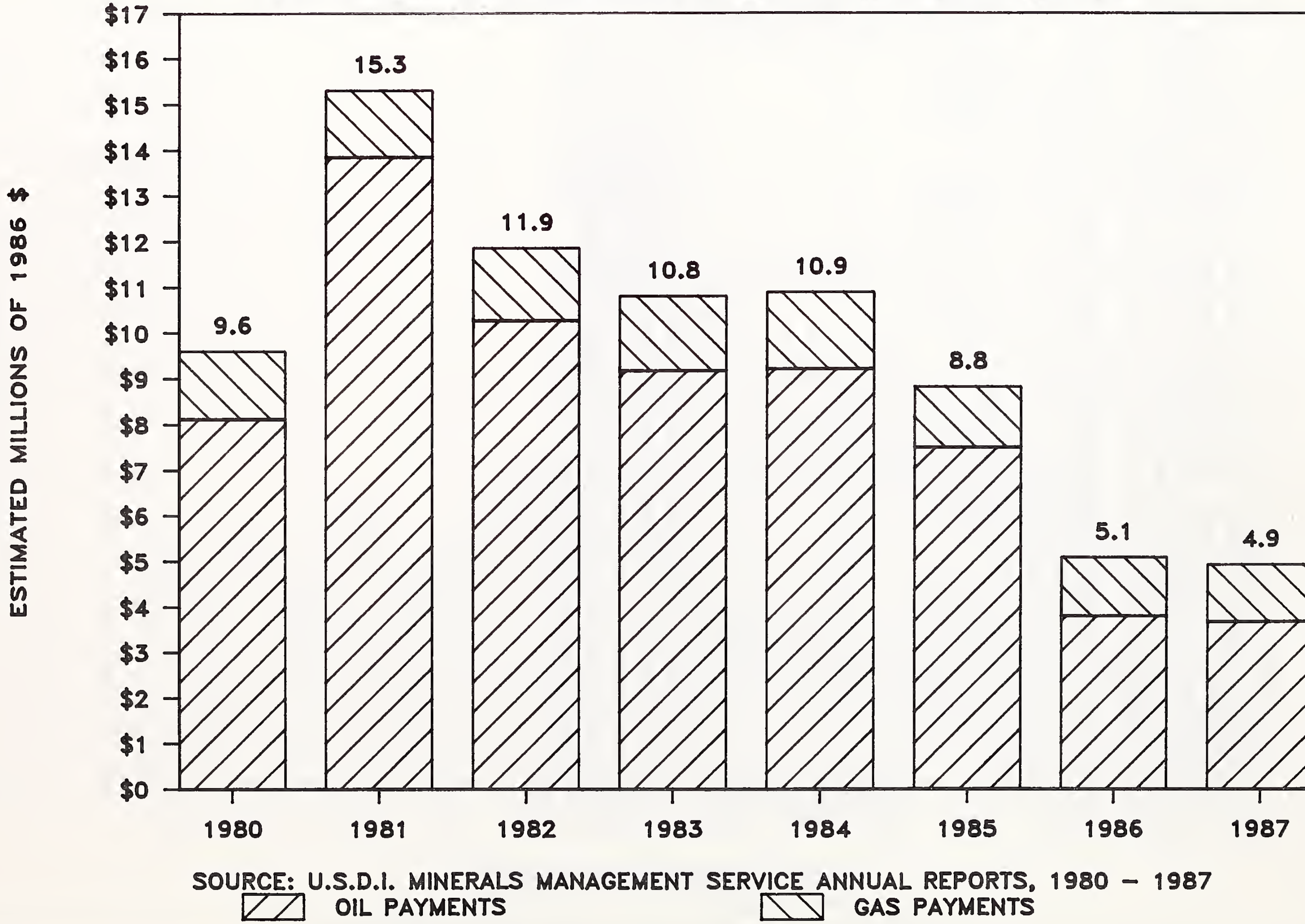
	Oil Payments to the State	Natural Gas Payments to the State	Total Oil and Gas Royalties	Percent of Total Federal Royalties Resulting from Oil and Gas Production
1980	$ 6.0	$ 1.1	$ 7.1	84%
1981	11.3	1.2	12.4	80%
1982	9.0	1.4	10.4	68%
1983	8.4	1.5	9.9	71%
1984	8.7	1.6	10.3	67%
1985	7.3	1.3	8.5	52%
1986	3.8	1.3	5.1	31%
1987	3.8	1.3	5.1	21%

U.S. Department of Interior, Minerals Management Service, Mineral Revenues: The 1986 Report on Receipts from Federal and Indian Leases; Washington D.C. 1987.
U.S. Department of Interior, Minerals Management Service, Mineral Revenues: The 1984 Report on Receipts from Federal and Indian Leases; Washington D.C. 1985.
Don Hoffman, Montana Department of Revenue 1988. (Table is based on federal fiscal year.)

FIGURE 11-14

ESTIMATED FEDERAL ROYALTIES PAID TO MONTANA

from OIL AND GAS PRODUCTION from FEDERAL MINERALS IN MONTANA



SOURCE: U.S.D.I. MINERALS MANAGEMENT SERVICE ANNUAL REPORTS, 1980 – 1987

TECHNICAL APPENDIX 12
LISTING OF SIGNIFICANT MONTANA PALEONTOLOGICAL RESOURCES
(from NRIS - Rivers Study Data Base - Value Class "1" or Designation "4")

Oil and Gas Region	County	Feature	NRIS Site #
Overthrust	Beaverhead/Madison	Beaverhead Rock Fossil Site	6-464
	Beaverhead	Grasshopper Creek Tertiary Deposits	6-495
	Beaverhead	Mill Point Site	6-497
	Beaverhead	Horse Prairie Fossil Area	6-481
	Beaverhead	Grant Fossil Locality	6-498
	Beaverhead	Medicine Lodge Creek Fossil Site	6-484
	Beaverhead	Bannock Pass Tertiary Beds	6-482
	Beaverhead	Armstead Fossil Site	6-489
	Beaverhead	Diamond "O" Fossil Site	6-461
	Beaverhead	Devil's Hole	6-57
	Beaverhead	Sage Creek Fossil Beds	6-81
	Broadwater	Beaver Creek Badlands	6-454
	Broadwater	Deep Creek Fossils	6-503
	Broadwater	Dry Creek Fossils	6-504
	Broadwater	Canyon Ferry Fossil Area	6-455
	Gallatin	Mounds and Reefs - Bridger Range	6-442
	Gallatin	Logan Gravel Pits - #1	6-435
	Gallatin	Logan Gravel Pits - #2	6-436
	Gallatin	Anceney	6-434
	Gallatin	Nixon Gulch Fossil Site	6-582
	Gallatin/Jefferson	Climbing Arrow Formation	6-172
	Gallatin	Buffalo Jump Fossil Area	6-443
	Granite	Maywood Ridge Fossil Site	6-493
	Jefferson	Big Pipestone Fossil Beds	6-77
	Jefferson	Negro Hollow Sites	6-440
	Jefferson	McKanna Springs	6-441
	Jefferson	Shoddy Creek Beds	6-439
	Jefferson	Little Pipestone Fossil Beds	6-78
	Lewis and Clark	Stromatolites	6-621
	Lewis and Clark	Oyster Shell Fossils	6-459
	Lewis and Clark	Rogers Pass Stromatolites	6-620
	Madison	Ruby Flora	6-80
	Madison	Lower Ruby Fossil Area	6-453
	Madison	Burnt Hills Locality	6-462
	Madison	Sweetwater Creek Fossil Insect Site	6-79 6-79
	Madison	McCartney Mountain Fossil Beds	6-72
	Madison	Gravelly Range Oligocene Fossils	6-883
	Missoula	Miocene-age Fossil Leaves	6-946
	Missoula	Overturned Fold, Cambrian Trilobites	6-496

Oil and Gas Region	County	Feature	NRIS Site #
Overthrust	Park	Bangtail Creek Fossil Bird Locality	6-913
	Park	Chalk Cliffs Fossils Locality	6-471
	Powell	Douglas Creek Beds	6-488
	Powell	Sturgeon Creek Fossil Site	6-489
	Powell	Nevada Creek - Helmville Beds	6-490
	Powell	Williams and Tavener Ranch	6-444
	Powell	Dempsey Creek Fossil Site	6-445
	Powell	Prison Camp Fossil Site	6-446
	Sanders	Gordon Shale Fossils	6-106
	Silver Bow	Fossil Location (Big Hole)	6-450
	Silver Bow	Fleecer Mountain Fossil Site	6-449
Northern	Cascade	Belt Creek Fossil Site	6-570
	Cascade	White Bear Island	6-474
	Glacier	Mission Lake Fossil Site	6-877
	Glacier	Milk River Valley	6-152
	Hill	Milk River Badlands	6-162
	Hill	Kennedy Coulee	6-874
	Teton	Nunemaker Coulee	6-876
	Teton	Egg Mountain	6-875
	Teton	Blackleaf Formation Invertebrates	6-610
Williston Basin	Fallon	Ollie Fossil Site	6-920
	Fallon	Hell Creek Exposure	6-907
	Fallon	Willard Micro Fossils	6-906
	McCone	Bug Creek Fossil Area	6-154
	McCone, Valley and Petroleum	CMR Wildlife Refuge Fossil Area	6-885
	McCone	Redwater Fossil Site	6-616
Central	Fergus	Lewistown Brickyard	6-486
	Fergus	Limekiln Fossil Site	6-485
	Fergus	Heath Fossil Site	6-578
	Fergus, Judith Basin	Reptile Fossils - Cretaceous	6-432
	Fergus	Bear Gulch Fauna	6-492
	Fergus	Bear Canyon- Rose Canyon Fossils	6-433
	Garfield	Garbony Quarry Fossil Site	6-478
	Garfield	Hell Creek Fossil Area	6-157
	Garfield	Snap Creek Fossil Area	6-884
	Golden Valley	Careless Creek Fossil Area	6-910
	Judith Basin	Bandbox Mountain	6-117
	Meagher	Park Hills Fossils	6-505
	Meagher	Smith River Fossil Site	6-456
	Musselshell	Fossil Plants	6-688
	Petroleum	Flatwillow Fossil Site	6-674
	Wheatland	Middle Dome fossils	6-908

Oil and Gas

Region	County	Feature	NRIS Site #
Big Horn	Big Horn	Cloverly Formation Site	6-155
	Carbon	Bridger Fossil Area	6-153
	Sweet Grass	Melville Fossil Site	6-909
Powder River	Carter	Ophiomorpha Fossil Site	6-904
	Carter	Medicine Rocks Fossil Site	6-905
	Custer	Blue Mountains	6-825
	Custer	Fossil Leaves near Miles City	6-670

GUIDELINES FOR THE DESIGN

AND CONSTRUCTION

OF LINED EVAPORATION PITS

(Revised 5/85)

Southeast Region
NEW MEXICO OIL CONSERVATION DIVISION

STATE LAND OFFICE BUILDING
SANTA FE, NEW MEXICO

PREFACE

The following specifications shall be used as a guide to the preparation of plans and specifications for lined evaporation ponds to be used to contain those liquid discharges regulated by the Oil Conservation Division. All plans and specifications shall be submitted to the Oil Conservation Division for approval prior to construction. Designs may deviate from the following specifications if it can be shown that the design integrity is such that the construction of that pit will not affect any present or future sources of usable ground water. Please note that this guide does not take precedence over any specifications outlined in the Oil Conservation Commission's Order No. R-3221-C.

GUIDELINES FOR APPLICATION FOR LINED EVAPORATION PIT PERMITS

These guidelines are to be used as a complement to "Guidelines for the Design and Construction of Lined Evaporation Pits".

I. GENERAL INFORMATION
Include the following with your application:

A. Name of Owner or Legally Responsible Party
Include address and telephone number.

B. Name of Local Representative or Contact Person (if different from above)
Include address and telephone number.

C. Location of Evaporation Pit
Give a legal description of the location (i.e. ¼ ¼, Section, Township, Range) and county. Use state coordinates or latitude/longitude on unsurveyed land. Submit a large scale topographic map, site plan, or detailed aerial photograph for use in conjunction with the written material. It should depict the locations of the evaporation pit(s), skimmer pond, and above and below grade tanks, and the other site information required in Sections II through V below.

D. Type of Operation

Indicate the major purposes(s) of the facility (eg. produced water evaporation pit) and briefly describe the processes occurring at the facility.

E. Copies

Provide two (2) copies of the application to the Santa Fe office. OCD will make copies available for District offices and public review as requested.

F. Affirmation

Include the following affirmation and signature with the application:

"I hereby certify that I am familiar with the information contained in and submitted with this application and that such information is true, accurate and complete to the best of my knowledge and belief."

(Signature)	(Date)
(Printed Name of Person Signing)	(Title)

II. GENERAL DESCRIPTION

A. Proposed Operations

1. Disposal Facilities Description:

Describe proposed on-site facilities to be used for effluent disposal of process/produced water, sludges, waste oils, etc., including surface impoundments, disposal pits, below grade tanks, and application, etc. Locate the various disposal areas on the facility site plan or topographic map. If materials or effluents other than produced water are proposed to be discharged at the site, describe in detail and provide volumes per day.

2. Technical Information:

Provide technical data on the design elements of each disposal method:

(a) Surface impoundments - Dates of use, type and volume of effluents stored, area, volume, depth, slope of pond sides, sub-grade description, liner type and thickness, compatibility of liner and effluents, installation methods, leak detection methods, freeboard, runoff/runon protection.

(b) Drying beds or other pits - Types and volumes of waste, area, capacity, liner, clean-out interval and method, and ultimate disposal location.

(c) Other on-site disposal (eg. land application etc.) - Describe.

3. Ancillary equipment

Provide details on aerators, sprayers or other equipment, including number, capacity, etc.

B. <u>Spill/Leak Prevention and Procedures</u>

1. Describe procedures addressing containment and cleanup in case of leaks from the lined evaporation pit, skimmer pond or below grade tank. Include information as to whether areas are bermed and drained to sumps, proposed schedule for OCD notification of leaks, etc.

2. Describe methods used to detect leaks and ensure integrity of above and below ground tanks and pond & pit liners. Discuss frequency of inspection and procedures to be undertaken if significant leaks are detected.

III. SITE CHARACTERISTICS
(See also Section IV)

A. <u>Hydrologic Features</u>

1. Provide the name, description, and location of any bodies of water, streams (indicate perennial or intermittent), or other watercourses (arroyos, canals, drains, etc.); and ground water discharge sites (water wells, seeps, springs, marshes, swamps) within one mile of the outside perimeter of the facility. For water wells, specify use of water (eg. public supply, domestic stock, etc.)

2. It is suggested that you:

a) Provide the total dissolved solids (TDS) concentration (in mg/l) of the ground water most likely to be affected by any discharge. Include the source of the information and how

it was determined.

b) Provide a recent water quality analysis of the ground water, if available, including name of analyzing laboratory and sample location and date. This suggestion is made so that background information is available in case of leaks or charges of neighboring groundwater contamination.

3. If known, provide the flow direction of the ground water most likely to be affected by any leaks. Include the source of the information and how was it determined.

B. <u>Geologic Description of Pit Site</u>
Provide the following information and attach or reference source information as available (eg. driller's logs):

1. Soil types(s) (sand, clay, loam, caliche);

2. Name and depth to water of most shallow aquifer(s):

3. Composition of aquifer material (eg. alluvium, sandstone, basalt, etc.); and

4. Depth to rock at base of alluvium if available).

C. <u>Flood Protection</u>

Provide information on:

1. The flooding potential at the pit site with respect to major precipitation and/or run-off events; and

2. Flood protection measures (berms, drainage channels, etc.), if applicable.

3. Notification of OCD in case of flooding or washout.

IV. ADDITIONAL INFORMATION

Provide any additional information necessary to demonstrate that approval of the pit application will

not result in contamination of fresh water (as described by OCD Rules) at any place of withdrawal of water for present or reasonably foreseeable future use. Depending on the methods of lining and location of pit, detailed technical information on site hydrologic and geologic conditions <u>may</u> be required to be submitted for pit application evaluation. This could include but not be limited to:

(1) Stratigraphic information including formation and member names, thickness, lithologies, lateral extent, etc.

(2) Generalized maps and cross-sections;

(3) Potentiometric maps for aquifers potentially affected;

(4) Porosity, hydraulic conductivity, storativity, and other hydrologic parameters of the aquifer;

(5) Specific information on the water quality of the receiving aquifer; and

(6) Information on expected alteration of contaminants due to sorption, precipitation or chemical reaction in the unsaturated zone, and expected reactions and/or dilution in the aquifer.

1. <u>LOCATION</u>

(A.) Evaporation pits shall not be located in any watercourse, lakebed, sink-hole, or other depression. Pits adjacent to any such watercourse or depression shall be located safely above the high-water level of such watercourse or depression.

2. <u>DESIGN AND CONSTRUCTION</u>

(A.) Evaporation pits shall be so designed and constructed to provide the minimum evaporative surface area needed for the maximum yearly volume of liquid to be discharged to the pit. This design parameter shall be based upon local climatological data. Such data and calculations used for the pit design shall be submitted with any proposed plans and specifications. Special care should be taken when calculating the pit volume to account for the decrease in the evaporation rate during the winter months.

(B.) Pits shall be located on level ground and shall be rectangular. Excavated material may be used to form levees around the pit. The levees shall rise a minimum of 18 inches above ground level.

(C.) The design freeboard allowance shall take wave action into account to prevent overtopping due to wave action. A determination of the wave type (breaking or non-breaking) shall be made to determine the forces acting upon the levee. Such calculations shall be submitted with the details for pit construction.

(D.) The pit is to be constructed so that the inside grade of the levee is no steeper than 2:1. Levees shall have an outside grade no steeper than 3:1 (See Figure 1).

(E.) The top of the levees shall be level and shall be at least 18 inches wide.

(F.) The pit shall incorporate a double liner system with a leak detection system installed between the primary (top) and secondary (bottom) liner.

3. <u>MATERIALS</u>

(A.) Materials used for lining evaporation pits shall be impermeable and may be rigid, semi-rigid, or flexible.

(B.) If rigid or semi-rigid materials are used, leak-proof expansion joints shall be provided, or the material shall be of sufficient thickness and strength to withstand (without cracking) expansion, contraction, and

settling movements in the underlying earth.

(C.) If flexible membrane materials are used, they shall be of at least 30 mil thickness and shall have good resistance to tears or punctures.

(D.) All materials used for lining evaporation pits shall be resistant to hydrocarbons, salts, and acidic and alkaline solutions. The liners shall also be resistant to fungus and rot. The primary liner shall be resistant to ultra-violet light or provision made to protect the material from the sun as specified in Section 6 (F).

4. LEAK DETECTION SYSTEM

(A.) A leak detection system of an approved design shall be installed between the primary and secondary liner, and shall be inspected and approved by the OCD prior to installation of the primary liner.

(B.) Leak detection systems may consist of, but are not necessarily limited to, approved fail-safe electric detection systems or drainage and sump systems.

(C.) If an electric grid detection system is used, provision must be made for adequately testing all components to ensure the system remains functional.

(D.) If the drainage and sump system is to be used, a network of slotted or perforated drainage pipes shall be installed between the primary and secondary liners. The network shall be of sufficient density so that no point in the pit-bed is more than 20 feet from such drainage pipe or lateral thereof. The material placed between the pipes and laterals shall be sufficiently permeable to allow transport of the fluids to the drainage pipe. The slope for all drainage lines and laterals shall be at least 6 inches per 50 feet. The slope of the pit-bed shall also conform to these values to assure fluid flow towards the leak detection system. The drainage pipe shall convey any fluids to a concrete or corrosion-proof sump located outside the perimeter of the pond (See Figure 2).

5. PREPARATION OF PIT-BED FOR INSTALLATION OF LINERS

(A.) The bed of the pit and inside grade of the levee shall be smooth and compacted, free of holes, rocks, stumps, clods, or any other debris which may rupture the liner. In extremely rocky areas, it will probably be necessary to cover the pit-bed with a compacted layer of sand or other suitable material.

(B.) A trench shall be excavated on the top of the levee the entire perimeter of the pit for the purpose of anchoring

flexible liners. This trench shall be located a minimum of 9 inches from the slope break and shall be a minimum of 12 inches deep. (See Fig. 3).

6. INSTALLATION OF FLEXIBLE MEMBRANE LINERS

(A.) Prior to installation of the secondary liner, the appropriate OCD district office should be notified at least 24 hours in advance of the scheduled installation to afford the opportunity for a Division representative to inspect the pit-bed and levee walls.

(B.) The pit liner shall be installed and joints sealed according to manufacturer's specifications and with approval of the Division representative.

(C.) The liner shall rest smoothly on the pit-bed and the inner face of the levees, and shall be of sufficient size to extend down to the bottom of the anchor trench and come back out a minimum of two inches from the trench on the side furthest from the pond. (See Fig. 3). In locations where temperature variations are significant, wrinkles or folds shall be placed at each corner of the pit to allow for the contraction and expansion of the membrane due to temperature variations. The membrane manufacturer should be consulted on this matter.

(D.) Certain conditions require the venting of gas that may accumulate beneath a liner. If organic matter exists in the soils under the liner, or if natural gas is present in the region, gas production is likely. When a fluctuating water table is present immediately below the pond bottom, pockets of air may also accumulate below the liner. The net result of gas or air accumulation below the liner may be the "floating" of the liner to the pond surface. Two possible vent designs are illustrated in Fig. 4. The need to vent this accumulated gas can be accomplished by providing a uniform layer of sand (which less than 5% will pass the 200 sieve) or a geotextile beneath the liners. To achieve the best results from either of these media, the slope from the lowest point of the pond to the toe of the dike must be at least 2%. The venting medium is carried across the entire bottom and up the side slopes. Vents should be located approximately one foot down from the crown of the dike. (See Figure 3).

(E.) An anchor of used pipe or other similar material shall be placed over the liner in the anchor trench and said trench back-filled. The anchor trench shall extend the entire perimeter of the pond.

(F.) If the lining material used for the primary liner is not sun-resistant, at least one inch of sand or other suitable material shall be spread uniformly to cover the liner over the floor of the pit. Gravel or other wave-resistant

material with sufficient angle of repose to remain in place shall be used to cover the sloping inner wall of the levee. A geotextile liner shall be placed beneath any gravel layer to provide protection for the membrane liner. Any gravel or sand layers used to protect the membrane liner from the sun shall extend to the anchor trench.

(G.) Any sand or gravel layers placed on top of a membrane liner shall be done so in such a manner that the risk of tearing the liner is minimized.

7. SKIMMER PONDS/TANKS

(A.) A skimmer pond or tank shall be used to separate any oil from the water prior to allowing the water to discharge to the evaporation pond, except for the following cases:

1) It can be shown that the water being discharged to the pond contains no oil or grease.

2) The discharge to the pond is from an oil or natural gas processing facility where the discharge has already passed through a skimmer basin, skimmer tank, decanter, or API Separator.

(B.) The skimmer pond/tank shall be designed to allow for a one-hour fluid residence time prior to discharge to the pond. The flow rate basis for the design volume shall be the maximum discharge to the pond in a one-hour period.

(C.) If a skimmer pond is to be used, the pond shall conform to the same specifications as the evaporation pond.

(D.) If a skimmer tank is to be used, the materials of construction and/or design shall provide for corrosion resistance.

(E.) If a skimmer pond is to be used, syphons or other suitable means shall be employed to draw water from the oil water interface for transfer to the evaporation pond. The siphon shall be located as far as possible from the inlet to the skimmer pond.

(F.) The skimmer pond/tank shall at all times be kept free of appreciable oil build-up to prevent oil flow to the evaporation pond.

(G.) Figures 5- a & b illustrate general design criteria for skimmer ponds and tanks, respectively.

8. FENCES AND SIGNS

(A.) A fence shall be constructed and maintained in good condition around the evaporation pit installation. The fences shall be

constructed so as to prevent livestock from entering the pit area. Fences shall not be constructed on the levees.

(B.) A sign not less than 12" x 24" with lettering of not less than two inches shall be posted in a conspicuous place on the fence surrounding the evaporation pit installation. The sign shall be maintained in legible condition and shall identify the operator of the evaporation system, the location of the system by quarter-quarter section, township, and range.

9. MAINTENANCE

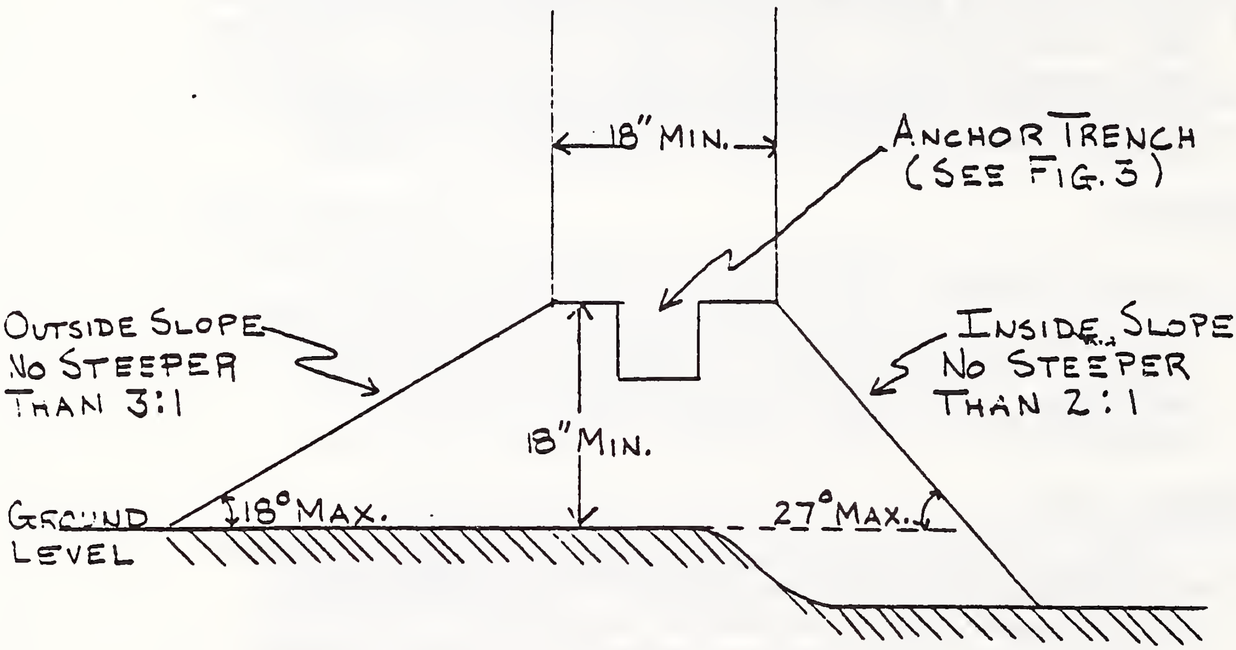
(A.) The leak detection sump shall be inspected at least weekly.

(B.) The outside walls of the levee shall be maintained in such a manner to prevent erosion. Inspections of the outside wall of the levee shall be made after any rainfall of consequence.

10. CONTINGENCY PLAN

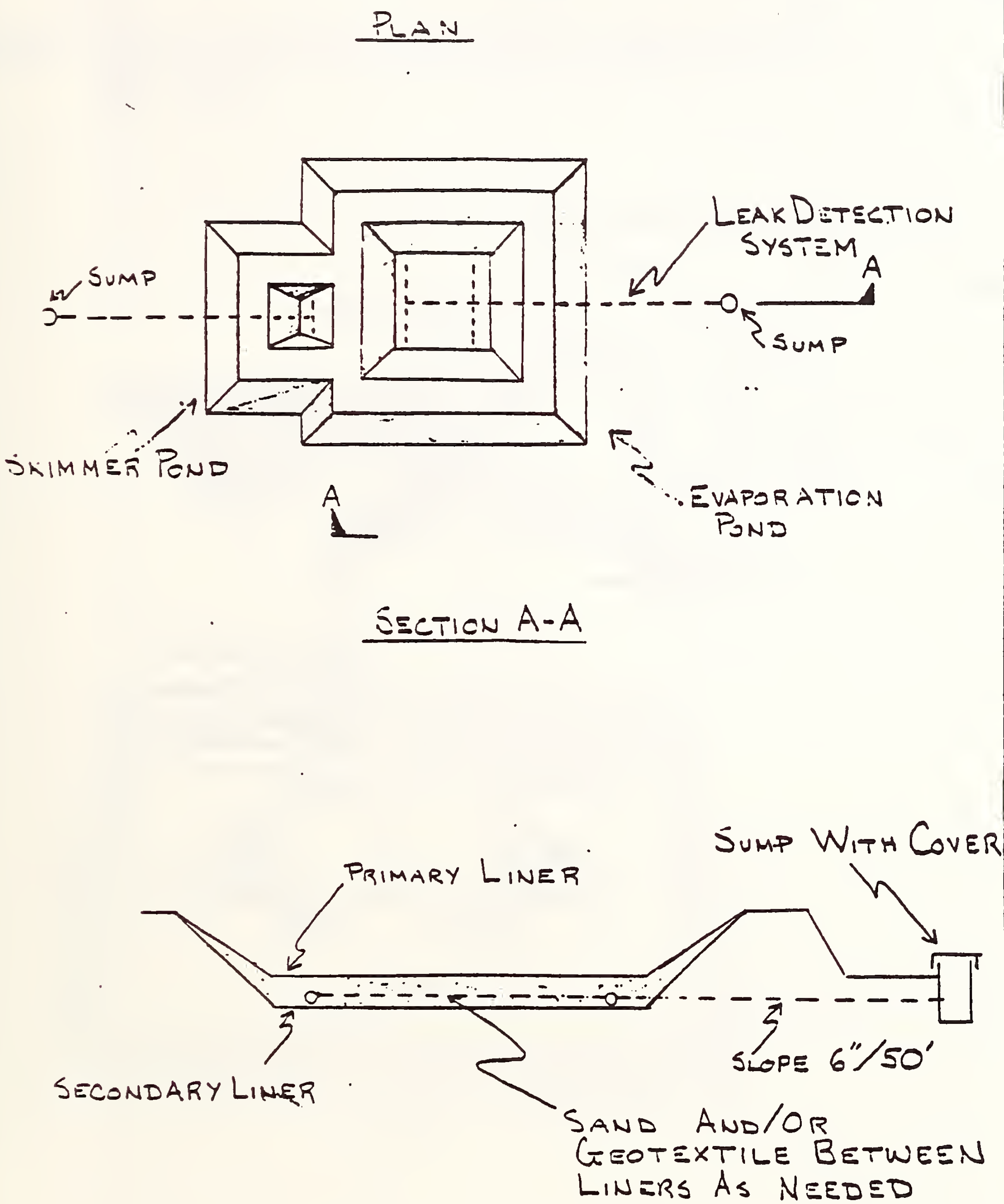
(A.) A contingency plan in the event of a leak shall be submitted for approval along with the details for pit construction. The contingency plan will outline a procedure for making repairs to the pit in the most expeditious manner possible.

FIGURE 1- PIT CONSTRUCTION



NOTE: LEVEE TO BE CONSTRUCTED IN A MANNER SUCH THAT DESIGN COMPACTION AND DIMENSIONS PROVIDE FOR A MINIMUM SAFETY FACTOR OF TWO FOR FORCES ACTING AGAINST THE LEVEE.

Figure 2 - Leak Detection System



Note: Skimmer Pond To Have Separate Leak Detection System And Sump.

FIGURE 3 - ANCHOR TRENCH

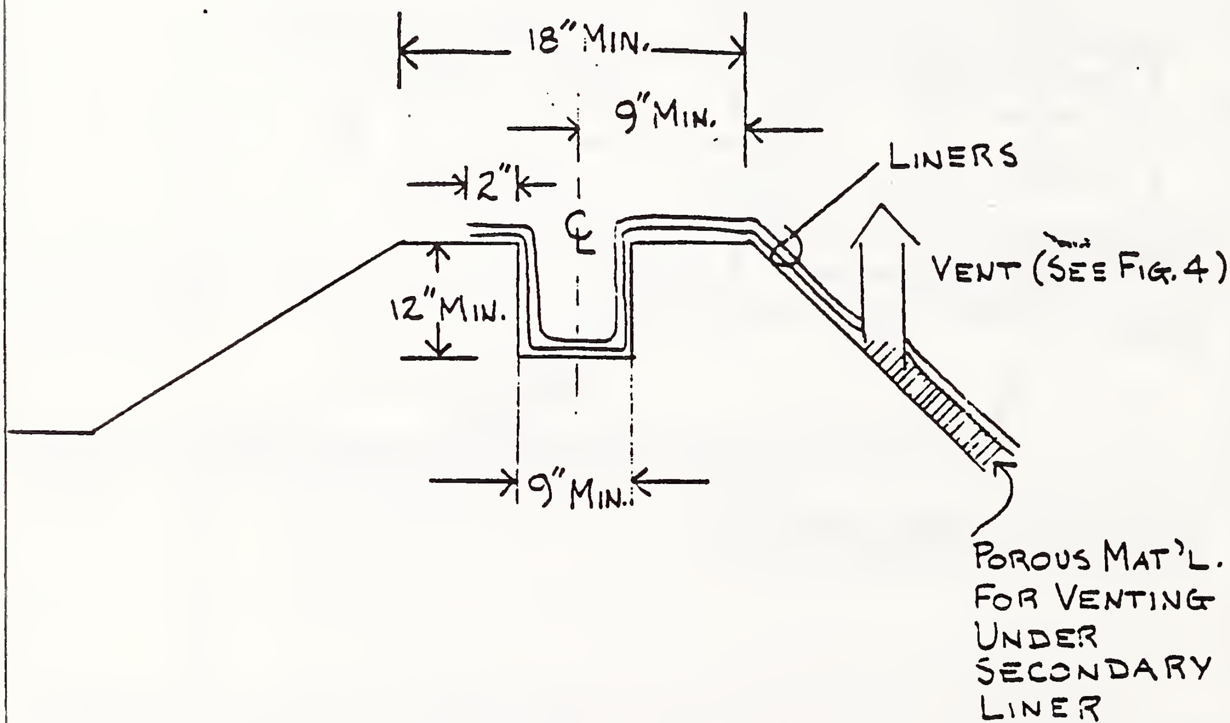
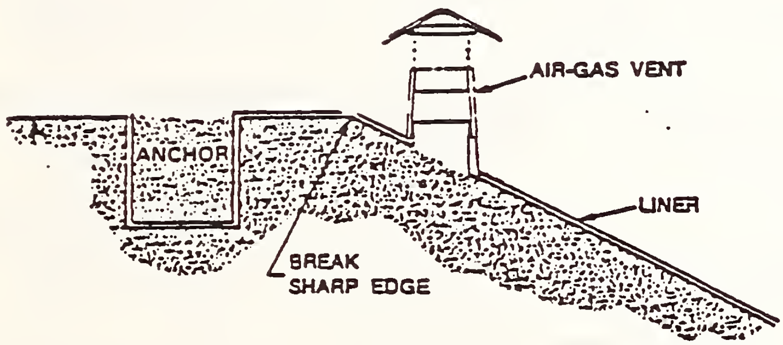


FIGURE 4 - TWO EXAMPLES OF VENT DESIGNS

SOURCE: EPA REPORT #SW-870, "LINING OF WASTE IMPOUNDMENT FACILITIES", PG. 260



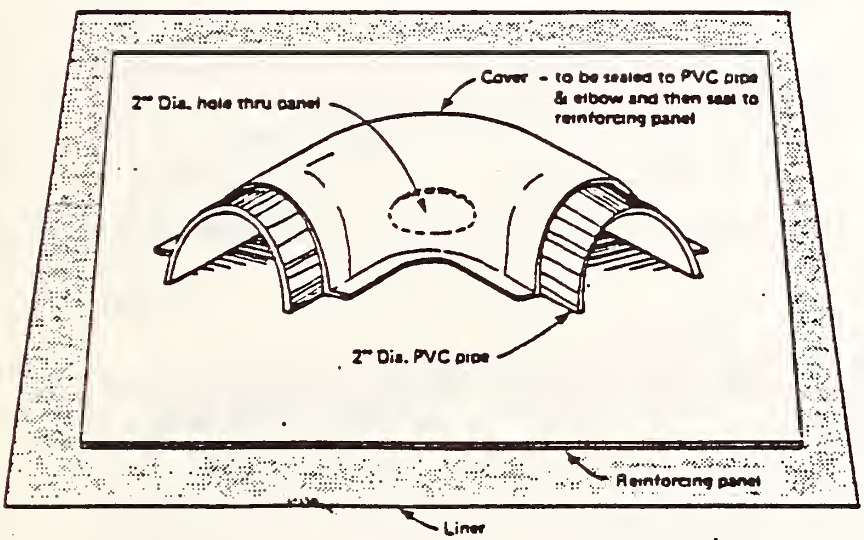
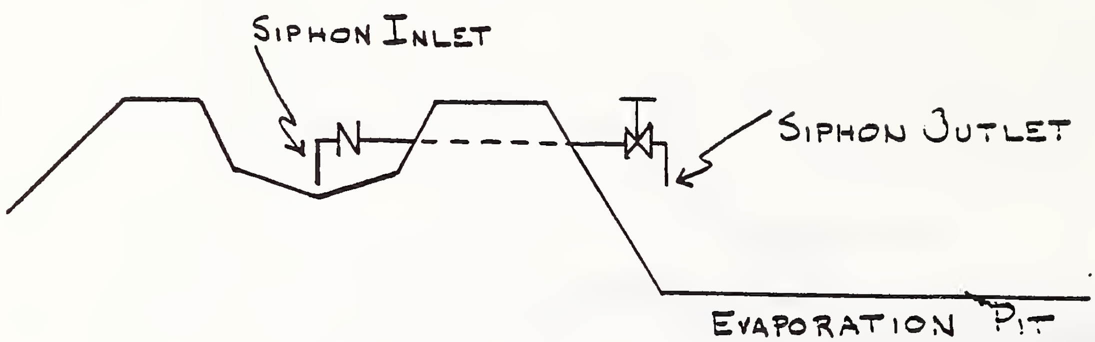
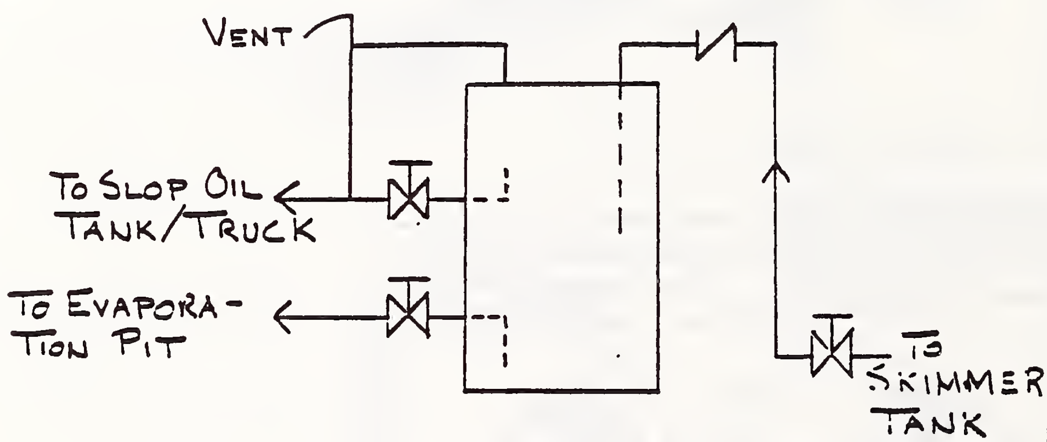


FIGURE 5: SKIMMER POND/TANK

(A.) SKIMMER POND



(B.) SKIMMER TANK



NOTE: BEFORE BEGINNING DISCHARGES TO SKIMMER POND/TANK, FILL WITH FRESH WATER TO SIPHON INLET.

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